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THE GEOLOGY

OF THE

ENGLISH LAKE DISTRICT

WITH NOTES ON THE MINERALS,

BY

JOHN POSTLETHWAITE, F.G.S.

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CARLISLE:
G. & T. COWARD, PRINTERS, FISHER STREET.
1906.

PREFACE.

The subject matter contained in the following pages was originally published in an abridged form, as the first part of a short treatise on "Mines and Mining in the Lake District;" but as the students of geology greatly exceed in number those who are interested in mining, and as there is a constantly increasing demand for a short and portable description of the geology and minerals of the Lake District, I was induced to enlarge slightly and re-publish that part of the book separately.

It has been my greatest pleasure, for upwards of twenty years, to search amongst the ancient sedimentary rocks of our mountains and valleys for the remains of life they contain, and I have endeavoured to give in these pages a fairly complete description of those remains of life. The section on the Mollusca is the only account that has been published of these fossils, as they occur in the Skiddaw Slate Rocks.

In compiling this work, I have been greatly indebted to the works of the late James Clifton Ward, F.G.S., who mapped and described the northern part of the English Lake District in a most careful and efficient manner, when employed on the

Geological Survey. I have also obtained and made use of information from the writings of other authors, including the Officers of the Geological Survey, who mapped and described other portions of the District, and I acknowledge my indebtedness to them.

My very best thanks are also due to Miss Hoare, of Leamington, for her kind and efficient help in making drawings of sections, and also of graptolites, trilobites, and brachiopods.

THE AUTHOR.

Keswick, May, 1897.

PREFACE TO SECOND EDITION.

In preparing for the issue of a Second Edition of this book, I have revised, and thereby endeavoured to make it more complete, and additional lists and plates of fossils have been added. The section on the Mollusca of the Skiddaw Slates has been re-arranged, and the figures have been carefully drawn by an experienced and efficient artist.

In this form I trust that the book will be of service to geological students, and to the large, and annually increasing number of tourists who are interested in geology, and who desire to obtain, in a concise and portable form, some account of the rocks of the Lake Country, and of the remains of life they contain.

I would again acknowledge my indebtedness to the Maps and Memoirs of the Geological Survey, and to the writings of other authors whose works and opinions are quoted, and to whom I wish to tender my sincere thanks.

I am also greatly indebted to Miss Hoare, of Leamington, for her kind and efficient help in making drawings of fossils.

THE AUTHOR.

Keswick, May, 1906.

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THE GEOLOGY
OF THE
ENGLISH LAKE DISTRICT.

THE English Lake District possesses many features of interest for students of nature; its meteorological conditions, its varied and beautiful scenery, the fauna and flora of its mountains, valleys, rivers, lakes, and woods, all offer wide fields for patient investigation and research. But above all, it will be found that a careful study of the structure of its rocky framework, and the materials of which that framework is composed, together with the unravelling of its somewhat tangled geologic history, will abundantly repay the student. The sedimentary rocks exposed in the northern part of the area under consideration rank next in point of age to the oldest formation which contains undoubted remains of life; the volcanic rocks, which succeed those of sedimentary origin, cover a much wider area, and are not less varied in character and composition; the igneous, metamorphic, and secondary rocks are also equally interesting; while the mineral veins of the District, with their metalliferous and non-metalliferous contents, and the fossil contents of the sedimentary and calcareous rocks, all form special subjects for investigation.

Prior to the year 1879, the rocks which occupy the main area of the Lake District were regarded as part of the Silurian system, but the revised classification of the older palæozoic rocks, proposed by Professor Lapworth, in the *Geological Magazine* for January, 1879, is now generally adopted. Jonathan Otley, of Keswick, was the first to discover that the rocks of the Lake District are capable of being classed in three distinct groups, which were named by him, Clayslate, Greenstone, and Greywacke. These divisions were afterwards described in greater detail by Professors Sedgwick, Phillips, and Harkness; and still later by Professor Nicholson, F.G.S., by whom they were classed as follows:—Skiddaw Slates, Green Slates and Porphyries, and Coniston Limestone, Flags, and Grits. In 1876, J. Clifton Ward's "Memoir of the Geology of the Northern Part of the English Lake District" was published, and in 1879 "The Physical History of the English Lake District," by the same author. In these, Mr. Ward renamed the Green Slates and Porphyries, "The Volcanic Series of Borrowdale."

More recently (1900), Mr. John E. Marr and Mr. Alfred Harker read a Paper to the Members of the Geologists' Association, entitled "Notes on the Geology of the English Lake District.[*] In this Paper the old name "Green Slates and Porphyries" is again given to the Volcanic Series, and the three great divisions of strata are described by the authors, under the appellations of "Lower Slates, Middle Slates, and Upper Slates."

Combining the arrangements of former workers, I propose to adopt the following classification:—

Anthropozoic	Recent . .	Post Glacial.
		Glacial.

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[*] Proceedings of the Geologists' Association, 1900, Vol. XVI., page 440.

Deuterozoic	Permian	Upper Permian.
		Lower do.
	Carboniferous	Coal Measures.
		Carboniferous Limestone Series
Proterozoic	Silurian	Ludlow.
		Coniston Flags and Grits.
		Stockdale Shales.
	Ordovician	Coniston Limestone Series
		Volcanic Series of Borrowdale.
		Skiddaw Slates.

SKIDDAW SLATES.

The Skiddaw Slates occupy the north-western portion of the Lake District, and cover an area of about 200 square miles. The western, north-western, and eastern boundaries of this area are formed by carboniferous limestone, and it is bounded on the north and north-east by the volcanic rocks of the Caldbeck mountains. On its south-eastern margin, which extends in a somewhat irregular course from Swinescales Beck, near Penruddock, by Mellfell and Threlkeld Common, to the foot of Walla Crag; thence along the eastern shore of Derwentwater, and over Maiden Moor, to the northern end of Honister Pass, it is succeeded, as far as the western side of Mellfell, by conglomerate; and from that point onward to Honister Pass, by the volcanic rocks of the Borrowdale Series, which are thrown down by a fault, extending along the whole length of the south-eastern margin. And on the south, from the northern end of Honister Pass, to Dent Hill, near Egremont, this area is bounded partly by the Buttermere and Ennerdale Granophyre, and partly by the Borrowdale Series. There is an isolated exposure of Skiddaw Slate at the south-western corner of the Lake District, including Black Combe mountain; and two exposures on the eastern side, namely, one at the lower end of Ullswater, and the other extending from the neighbourhood of Butterwick, to Thornship, near Shap. There is probably a very extensive area of Skiddaw Slate buried beneath strata of a later date, and it was no doubt once continuous with the sedimentary rocks of the Isle of Man, and those of Wales and Ireland.

The Skiddaw Slate Rocks consist of a series of beds of soft shale, or slaty mudstone, interstratified with occasional beds of micaceous grit. The slaty mudstone, which forms the most important part of the series, is a soft black or dark grey rock, frequently containing cubes of iron pyrites, and in some places oval-shaped ferruginous nodules of various sizes. This rock has been subjected to great lateral pressure, by which it has been cleaved, crumpled and contorted, and most of it breaks up into splintery and pencil-like fragments; but in localities, where the cleavage coincides with the bedding, it splits readily into thin leaves. The stone is of little value commercially, as it rapidly falls to decay when exposed to the atmosphere. The beds of grit are occasionally of considerable, but irregular thickness, generally more or less micaceous, and of a hard and durable character. In some localities the grit is coarse and sandy, breaking up into square or oblong blocks; in others it is formed of finer materials, and is of a flaggy nature. In either case it forms a good and durable building stone. These beds have also suffered from the lateral pressure which acted on the softer strata, but in a much less degree.

These alternating beds of fine and coarser mud and sand, hardened by age and pressure, which probably attain a thickness of from 10,000 to 12,000 feet, represent old marine deposits of river and current-borne materials. There are no indications of deep sea deposits, but rather those of shore conditions. To allow of such an accumulation of deltaic deposit, there must have been a continual depression of the area of deposition, during a period of time which has been variously estimated at from one and a half to six millions of years.

During the whole of this time, whether longer or shorter, the sea was inhabited by multitudes of living creatures, some being of a very low type, and others more highly organised. There was vegetable life, too, in the shape of sea-weed and marsh plants, on which some of the animal forms probably fed, while the rest would prey upon each other, or upon more minute organisms, of which the rocks contain no record. The remains of vegetable life are but scanty and imperfect, a fact which need cause no surprise if we consider their frail and perishable nature, and the immense lapse of time since they were buried in those ancient deposits of mud and sand. There are, however, impressions occasionally met with which may be regarded as undoubted specimens of the flora of the Ordovician Age. Those hitherto obtained from the Skiddaw Slates are:—

Buthotrephis flexuoso. Hall.
„ Harknessi. Nich.
Buthotrephis? radiata. Nich.
Eophyton? palmatum. Nich.

The forms of animal life which were fossilized in those ancient rocks were of a much more enduring character, as they were enclosed in horny or calcareous cases, which would resist the ordinary decay of nature much longer, and thus afford greater facilities for fossilization.

The quiet bays and lagoons of the primitive delta before mentioned were inhabited by an assemblage of living creatures called "Graptolites," the fossilized remains of which consist of leaf-like or branching grass-like bodies, or the impressions of those bodies as they are now seen in the slaty mudstone in which they were then enclosed. There was much variety of form amongst them, although all bore the common family likeness. Those fossilized forms are the remains of chitinous or horny cases once inhabited by composite organisms, or they may be described as colonies of semi-independent creatures, which, when living, must have had a very marked resemblance, in many points, to the Sertularian Zoophytes that inhabit our seas at the present time. In general structure they consisted of one or more rows of horny cups or cellules, attached to a tube or common canal, into which they probably opened by a narrow aperture at their bases; and a slender rod, also attached to the common canal, but which often projected beyond both ends of it in young members, the distal prolongation, however, was less frequent in those of mature growth. Both the common canal and the slender rod, called the "Axis," were composed of the same horny material as the cellules.

Each portion of this compound organism fulfilled its own office. The axis, which formed the foundation or back-bone of the stipe or polypary, consisted of a slender fibrous cylinder or rod, extending along the side of the common canal opposite that on which the cellules were placed, or between the outer walls of the common canals in forms possessing two or more rows of cellules. The chief function of the axis was no doubt to give stability to the structure.

The "Common Canal," in which the general body was enclosed, consisted of a tube attached on one side to the axis, and on the opposite side were the cellules containing the Zooids.

The "Cellules," consisting of small cups or tiny tubes, were placed side by side along the common canal, and were inclined at various angles towards the upper or distal end, each cellule overlapping its neighbour to a certain extent.

Each Graptolite, of whatever species, had its origin in a small triangular or cone shaped body called the "Sicula," consisting of a chitinous cup, usually about the size of a cellule, and which contained the original germ of life from which the entire organism was afterwards developed.

When Graptolites were living organisms, there can be no doubt that each cellule contained a zoid, which was connected with the general body; and that this zooid, like the Sertularian Zoophytes of the present time, would be furnished with tentacles or arms for the purpose of securing its food. Also, that it would probably possess the power to protrude its head beyond the mouth of the cellule when necessary, and retire altogether within it when an enemy approached.

Neither the young nor the adult Graptolites appear to have been endowed with the power of locomotion: there is no trace in any of their fossilized remains of organs by which they could move from place to place. If they were really furnished with such organs, they must have been of a membranous nature, and, like the soft portions of their bodies, would perish and leave no trace behind. It must also be remembered that Graptolites were composite organisms, consisting in some cases of from two to three thousand semi-independent zooids; and we can scarcely imagine such numerous colonies acting in concert in reference to the direction in which they should travel. The limited knowledge we possess respecting the habits of these interesting creatures, points to the conclusion that, although they existed as free organisms, yet in all probability they performed the work assigned to them by a beneficent and all-wise Creator, and then died at the place which witnessed their birth.

In reference to the preservation of the remains of these organisms, it would seem that the stipes have generally been crushed or flattened out, but in some cases the process of fossilization has been completed before any great amount of pressure was applied; and thus the forms were preserved in relief. In the process of fossilization, the horny substance of which they were formed has often been replaced by iron pyrites, but in some cases it has been carbonized.

There is reason to believe that only a very small percentage of the Graptolites was fossilized; the remainder would decay and become mixed with the mud at the bottom of the sea, and thus supply the carbon that forms one of the constituents of the rock in which they are found. Some of the slates and shales that yield Graptolites most plentifully, contain as much as five per cent. of carbon, derived partly from decayed vegetation, and partly from the remains of these little creatures: indeed, it is more than probable that the dark colour and the anthracitic appearance of the most highly-fossiliferous beds may be due to that cause.

The oldest rocks in which Graptolites occur are the sedimentary beds forming the lower portion of the Ordovician series, of which the Skiddaw Slates form part, and they were by far the most abundant and characteristic creatures of the Ordovician Age.* They also lived on into the Silurian Age, as their remains are found in the lower part of the Silurian formation, then they disappeared altogether, and I believe there is no trace anywhere of their remains in all the vast series of rocks of later age, from the lower Silurian down to those most recently formed, representing immense cycles of geologic time; and yet the sea is now swarming with their living representatives. How strange it is, that their work in the economy of nature being incomplete, they should become extinct, and, after the lapse of untold ages, reappear almost unchanged. The chief points of difference between the ancient Graptolites and the modern Sertularians being that, whereas in the former an "axis" was always present, there is no trace of such an organ in the latter; also, that the Graptolites were free organisms, while the Sertularians are always attached to some object by a root-like process. In other respects the resemblance between the two is very close indeed.

---

*Lower Ordovician Rocks, containing Graptolites, also occur in the South of Scotland. North and South Wales, Shropshire, North and South of Ireland, Scandinavia, Belgium, Bohemia, and Canada; and it is very remarkable that the Graptolites of the Skiddaw Slates are, with the exception of one locality, namely, Ramsay Island, near St. David's in Wales, more closely allied to the Canadian group than to those found in any other locality in Britain.

About 120 species of Graptolites have been found in the lower and middle Ordovician Rocks of Great Britain, and of these 59 have been obtained from the Skiddaw Slates.

The following is a list of Genera and Species transcribed from Miss Elles's Paper on "The Graptolite Fauna of the Skiddaw Slates," in the Quarterly Journal for August, 1898, Vol. 54.

Fam. DICHOGRAPTIDÆ (Lapw.).

Genus 1. *Bryograptus*, Lapw.
  Sp. (a) *Br. ramosus*, Brögger, var. *cumbrensis* nov.
  (b) *Br. Kjerulfi*, Lapw.
  (c) *Br.* cf. *Callavei*, Lapw.

Genus 2. *Clonograptus*, Hall.
  Sp. (a) *Cl. flexilis*, Hall.
  (b) *Cl.* cf. *tenellus*, Linnarsson.
  (c) *Cl.* sp.

Genus 3. *Loganograptus*, Hall.
  Sp. *L. Logani*, Hall: various types

Genus 4. *Temnograptus*, Nich.
  Sp. *T. multiplex*. Nich.

Genus 5. *Pleurograptus*, Nich.
  Sp. *Pl. vagans*, Nich.

Genus 6. *Trochograptus*, Holm.
  Sp. *Tr. diffusus*, Holm.

Genus 7. *Pterograptus*, Holm.
  Sp. *Pt.* sp.

Genus 8. *Schizograptus*, Nich.
- Sp. *Sch. reticulatus*, Nich.
  - *Sch. tardifurcatus*, sp. nov.

Genus 9. *Trichograptus*, Nich.
- Sp. *Tr. fragilis*, Nich.

Genus 10. *Dichograptus*, Salt.
- Sp. *D. octobrachiatus*, Hall : various types.
  - *D. separatus*, sp. nov.

Genus 11. *Tetragraptus*, Salt.
- Sp. (a) *T. Bigsbyi*, Hall.
  - (b) *T. crucifer*, Hall.
  - (c) *T. Headi*, Hall.
  - (d) *T. pendens*, sp. nov.
  - (e) *T. Postlethwaitii*, sp. nov.
  - (f) *T. quadribrachiatus*, Hall.
  - (g) *T. serra*, Brongn

Genus 12. *Phyllograptus*, Hall.
- Sp. (a) *Ph. Anna*, Hall.
  - (b) *Ph. Angustifolius*, Hall.
  - (c) *Ph. ilicifolius*, Hall.
  - (d) *Ph.* ——, var. *grandis* nov.
  - (e) *Ph. typus*, Hall.

Genus 13. *Didymograptus*, M'Coy.
- Sp. (a) *D. affinis*, Nich.
  - (b) *D. bifidus*, Hall.
  - (c) *D. extensus*, Hall.
  - (d) *D. fasciulatus*, Nich.
  - (e) *D. gibberulus*, Nich.
  - (f) *D. gracilis*, Törnq.
  - (g) *D. indentus*, Hall.

(h) *D.* ——, var. *nanus*, Hopk. & Lapw.
(i) *D. Nicholsoni*, Lapw.
(k) *D. nitidus*, Hall.
(l) *D. patulus*, Hall.
(m) *D. V-fractus*, Salt.
(n) *D. V-fractus*, var. *volucer*, H. O. Nich.

Genus 14. *Azygograptus*, Nich. & Lapw.
Sp. (a) *A. Lapworthi*, Nich.
(b) *A. cœlebs*, Lapw.
(c) *A. suecicus*, Moberg.

Fam. NEMAGRAPTIDÆ, Hopk.
Genus *Leptograptus*, Lapw.
Sp. *L.* sp.

Fam. DICRANOGRAPTIDÆ, Lapw.
Genus *Dicellograptus*, Hopk.
Sp. *D. moffatensis*, Carr.

Fam. DIPLOGRAPTIDÆ, Lapw.
Genus 1. *Diplograptus*, M'Coy.
Sp. (a) *D. dentatus*, Brongn.
(b) *D. teretiusculus*, His.
(c) *D. appendiculatus*, Törnq. MS.

Genus 2. *Climacograptus*, Hall.
Sp. *Cl. Scharenbergi*, Lapw.

Genus 3. *Cryptograptus*, Lapw.
Sp. (a) *Cr. Hopkinsoni*, Nich.
(b) *Cr. antennarius*, Hall.
(c) *Cr. tricornis*. Carr

Fam. GLOSSOGRAPTIDÆ, Lapw.
  Genus *Glossograptus*, Emmons.
    Sp. (a) *Gl. armatus*, Nich.
      (b) *Gl. Hincksii*, Hopk.
      (c) *Gl. fimbriatus*, Hopk.

Fam. RETIOLITIDÆ, Lapw.
  Genus *Trigonograptus*, Nich.
    Sp. (a) *Tr. ensiformis*, Hall.
      (b) *Tr. lanceolatus*, Nich.

Fam. ?
  Genus. *Thamnograptus*, Nich.
    Sp. *Th. Doveri*, Nich.

ANNELIDA.

Numerous impressions of worm tracks occur in the Skiddaw Slates, but, so far as I know, no example of a fossilized worm has been found. The impressions they have left in the slate are well marked, and vary in width from less than an eighth to upwards of a quarter of an inch, and it would seem from those impressions that, when crawling, they have wandered on in the winding, uncertain, and apparently aimless way, so faithfully followed by their descendants at the present time; indeed, the worm tracks we see occasionally on our public highways, after a shower of rain, are a perfect representation of the impressions left in the Skiddaw Slate rocks. And the annelid of the early Ordovician Age had, no doubt, as important a task to perform as that claimed by Darwin for their descendants of to-day.

Impressions of a peculiar rayed body, called "Stella Scolites," which has been referred provisionally to the annelida, is met with occasionally. It consists of a depressed circular or oval-shaped disc, of variable size, from which a number of rays proceed on every side. The rays are narrow, but well rounded at the junction with the central disc, becoming broader and more flat at their extremities; it is probable that they were hollow originally, but their structure cannot be clearly determined. The diameter of the stellate body varies from one inch to eight or ten inches; and from the way in which the rays are lost in the matrix, they may have extended beyond that which now appears to be the margin, or extent of the rays. The number of rays also varies. I have had in my possession specimens which show twelve, fourteen, sixteen, and twenty-eight rays respectively. The origin of this peculiar fossil is very obscure, there is not sufficient evidence to show whether it represents the remains of an animal or its action only in the mud; but as it approaches very nearly to the form and structure of the radiating annelide burrows, which may sometimes be seen on our sandy shores, it has been classed with the Marine Annelida.

The ribbon-like and thread-like markings, called "Chondrites and Nematolites," that are found associated with the Graptolites, and for which some palæontologists have claimed an animal and others a vegetable origin, are probably the fossilized remains of worm tubes. Chondrites sometimes assumes a stellar form.

List of Annelids found in the Skiddaw Slates:—

Worm tracks and burrows.
Palæochorda major. Mc.Coy.
,, minor. Mc.Coy.
Chondrites acut-angulus. Mc.Coy.
,, informis. Mc.Coy.
Arenicolites.
Scolites.
Helminthites. Salt.
Stella-scolites radiatus. Etheridge.

CRUSTACEA.

Phyllopoda.

Next to the Graptolites, the most numerous and persistent of the Skiddaw Slate Fossils is the bi-valved Phyllopod, called "Caryocaris Wrightii." Its remains occur in almost every locality where Graptolites are found. It consists of a smooth oval-shaped carapace, with a distinct hinge line, one end is usually a little narrower than the other. They vary in length from three-eighths to three-quarters of an inch, and some very large specimens measure an inch; the width is about one-third of the length. The surface of the carapace is sometimes slightly wrinkled, but generally smooth and glistening, and the fossilized material, which is totally different from that of the Graptolites, appears to contain a certain amount of lime associated with a black carbonaceous substance.

List of Phyllopods found in the Skiddaw Slates :—

Caryocaris Wrightii. Salt.
,, ova of?
Ceratiocaris? sp. Baily.

TRILOBITA.

A small number of Trilobites (probably not more than thirty) have been found in the Skiddaw Slates. These fossils are the remains of some of the early representatives of an important order of extinct crustacea, belonging to the sub-class entomostraca. They are found only in palæozoic strata, extending from the upper Cambrian to the lower Carboniferous. The body of this crustacean was protected by a well-developed oval shell, the front portion of which covered the vital parts like a shield. This shield was divided longitudinally into three parts, the central and side pieces often varying considerably in shape, and in their relative proportions, in different species. The side pieces contained the eyes of the creature. The remainder of the shell was also divided longitudinally into three lobes, and consisted of a variable number of rings or segments, which were movable, being sufficiently flexible to allow the creature to roll itself up into a ball. In some species the segments gradually diminished in size to the extremity of the body, and in others there was a caudal shield, corresponding more or less in size and shape with the head shield. Trilobites were no doubt solitary in their habits, but possessed the power of moving about freely from place to place; their remains found in the Skiddaw Slates generally occur in isolated specimens scattered widely apart. They vary from a quarter of an inch to nine inches in length, and consist of prints or impressions of the dorsal shell only. It is evident, therefore, that if the ventral surface of the body was protected, the shell must have been of such a fragile character that it has perished, together with the legs, swimming appendages, and internal organs of the creature, the dorsal shell alone being sufficiently hard to retain its form until the mud, of which the Skiddaw Slate is formed, became solidified above and beneath it; hence, when the slate breaks up along the bedding planes, we find a cast only of the whole or a part of the internal or external surface of the shell. The shell itself, which would probably be formed of carbonate of lime, has no doubt been dissolved and removed at a later period, leaving no trace whatever of the original material, and thus causing an additional line of weakness in the slate, owing to which the subsequent exposure of the cast is very often due.

List of Trilobites found in the Skiddaw Slates:—

Phacops Nicholsoni. Salter.
Cybele ovata. Etheridge.
? Calymene brevicapitata.
? Remopleurides sp.
? Olenus sp.
? Trinucleus Gibbsii.
New genus, not named.
? Ogygia Selwyni.
? Ogygia sp.
Barrandea falcata, n.s., Postl. and Goodch.
Niobe Doveri. Etheridge.
Eurymetopus cumbrianus, n.g., and n. sp., Postl. and Goodch.
Eurymetopus Harrisoni, n.g., and n. sp., Postl. and Goodch.
Æglina ? rediviva. Barr.
Æglina ? binodosa.
Æglina obtusicaudata. Hicks.
Æglina ? caliginosa.
Aynostus morei. Salt.

Plate 1.

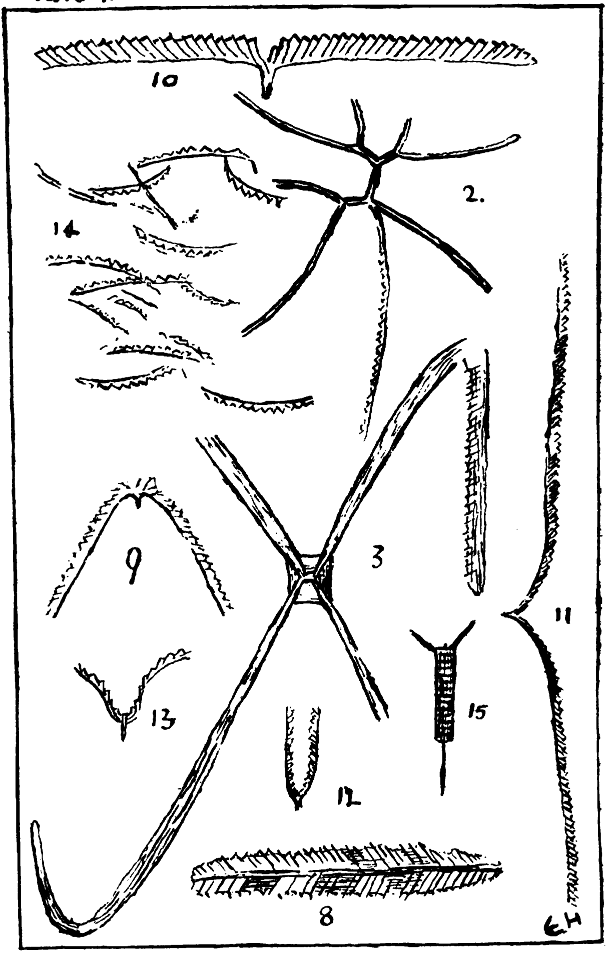
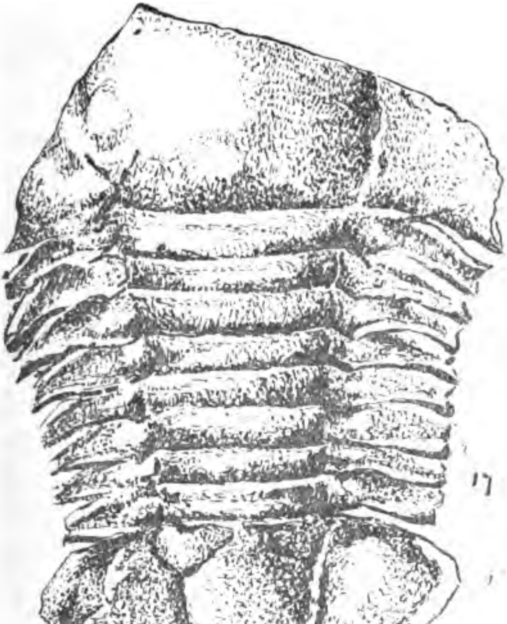


Plate II.



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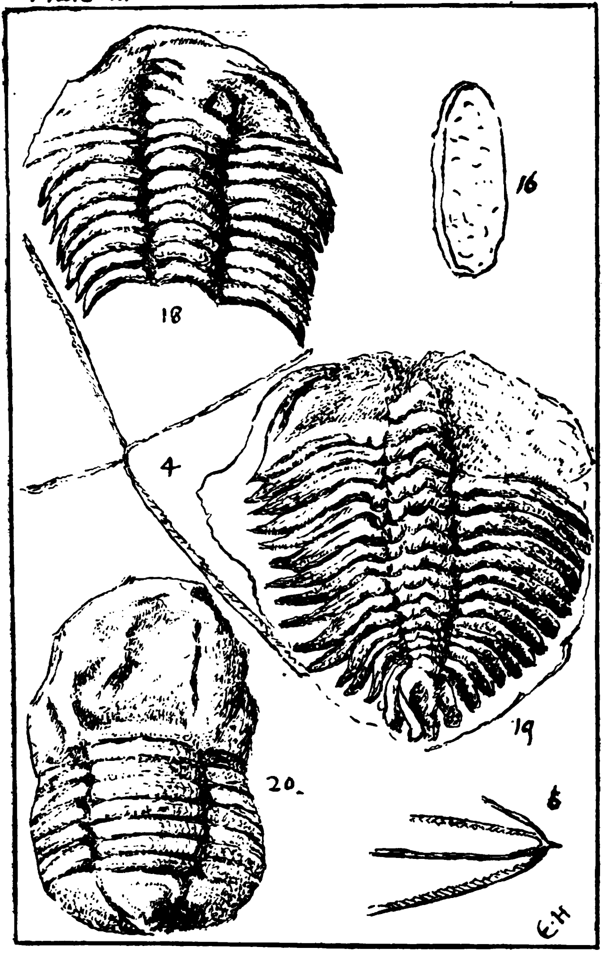
E.H

Plate III.



EXPLANATION OF PLATES.

PLATE I.

Fig. 2—Dichograptus separatus, sp. nov.
,, 3—Tetragraptus crucifer.
,, 8—Phyllograptus augustifolius.
,, 9—Didymograptus gibberulus.
,, 10— Ditto patulus.
,, 11— Ditto uniformis.
,, 12— Ditto nanus.
,, 13— Ditto deflexus.
,, 14—Azygograptus succicus.
,, 15—Cryptograptus antennarius.

PLATE II.

Fig. 1—Bryograptus Kjerulfi.
,, 5—Tetragraptus Bigsbyi.
,, 7—Phyllograptus typus.
,, 17—Eurymetopus Harrisoni.

PLATE III.

Fig. 4—Tetragraptus quadribrachiatus.
,, 6— Ditto Postlethwaitii.
,, 16—Caryocaris Wrightii.
,, 18—? Olenus sp.
,, 19—Cybele ovata.
,, 20—Æglina obtusicaudata.

MOLLUSCOIDA.

The fossil Mollusca, like their living descendants, were soft-bodied and possessed an exoskeleton or shell, usually formed of calcareous matter; and it is impressions of these shells, or the fossilized material by which they were replaced, that have been left in the rocks in which they occur. They also undoubtedly had many, probably all, the internal and other organs possessed by their living representatives, amongst which are an alimentary canal, a nervous system, cirriferous arms and tentacles, and in some species a heart and respiratory organs. Some were attached to foreign objects by a long muscular peduncle or stem, and others were entirely free. The Brachiopoda, the order to which most of the Skiddaw Slate fossil shells belong, were amongst the lowliest members of the molluscan sub-kingdom, but they were an important class in point of numbers, and in the persistency with which they held their ground in the great battle of life. They came into existence at the very dawn of life, in the Cambrian Age, and attained their maximum in the Silurian Age, which has sometimes been called the age of the Brachiopods. Numerous genera and species are, however, found in strata of more recent age and, although about 2,000 species have died out, there are nearly 100 living in our seas at the present time. The genus "Lingula" has been the most persistent of all the Brachiopods; the remains of this genus are first found in Cambrian Rocks, but they are also found in every succeeding geological formation, and the little creatures are still living in the sea at the present time, almost unchanged. In this respect they differ widely from the Graptolites and Trilobites with which their remains are associated in the Skiddaw Slates: the two former speedily succumbed, but the Lingula has maintained its position in a marvellous way in the face of all its enemies. It appears, however, to be slowly but surely dying out.

Fossil shells are extremely scarce in the Skiddaw Slate Rocks; indeed, the whole series has probably not yielded more than a score specimens, although a diligent search has been kept up for many years by a number of zealous and enthusiastic collectors; but some have no doubt escaped detection because, like the Trilobites, most of the specimens are casts only, and, being of the same colour as the slate in which the impression occurs, are not likely to arrest the eye of a collector, while others are so diminutive that they can scarcely be seen without the aid of a lens. The few specimens that have been obtained, consist of a single dorsal or ventral valve (in one or two only do we possess both valves of the same individual), in some cases it is a cast of the interior and in others of the exterior surface of the shell which has been preserved. Although the materials are so scanty they are not unimportant, as they prove that the Brachiopods and other shell-fish, whose remains were fossilized in the Skiddaw Slates, differed in some points from all known species, and thus invest with additional interest the ancient Ordovician Rocks in which they occur.

The shells that have been found in the Skiddaw Slates were figured and described by the author in the first edition of this little book, and as they are the remains of the most highly organised creatures that lived in the Ordovician Age, it is again considered desirable to describe them in greater detail than the lower organisms described in the preceding pages. Fortunately the author had the privilege of submitting some of the specimens to the late Thomas Davidson, and they were in each case pronounced by him to be new species; on these, therefore, he felt justified in bestowing names in the first edition, and now proposes to give names to all the remaining specimens that shew any distinctive features. The fossils have been carefully drawn by an experienced artist, and are in most cases enlarged about four times the actual size. (See plates 4 and 5.)

ORDER, MOLLUSCOIDA.

Class, Brachiopoda. Fam., Lingulidæ. Genus, Lingula.

Lingula Brevis.—Fig. No. 1. Shell small and rather flat, broadest near the middle, and obtusely rounded anteriorly; marked by concentric lines of growth.

Length 3/16ths and width 1/8th of an inch.

Locality, Outerside, about four miles S.W. from Keswick.

Carlisle Museum (Harkness Collection),

In the first edition of this book, this shell was named *Lingula Donaldii*, but since then the author has ascertained that it was figured and described by the late Thomas Davidson, as *Lingula Brevis*, in the Palæontographical Society's Journal, Vol. XIX., page 50, and plate 3, and the author feels sure no one would wish to dissent from his decision on any point respecting the Fossil Brachiopoda.

Lingula Carlioli.—Fig. No. 2. Shell almost a perfect oval in shape, 3/16ths of an inch in length, and 1/8th of an inch in width. It is flattened at the base, but well rounded towards the beak, and shows clearly marked lines of growth.

Close to this shell, on the same fragment of slate, are both valves of a smaller, probably an immature specimen of the same species, but so poorly preserved that the artist has not reproduced them.

Locality, Outerside. Carlisle Museum (Harkness Collection).

Lingula Hughesii.—Fig. No. 3. Shell very flat, an elongated oval in shape, 7/16 of an inch in length, and 1/4th of an inch in width, well rounded at the base, but sharply pointed at the beak. Lines of growth distinctly marked.

Locality, Outerside. Woodwardian Museum, Cambridge.

I have named this shell after Mrs. T. Mc.K. Hughes, by whom it was presented to the Musuem.

Lingula Dalii.—Fig. No. 4. Shell almost circular in shape, but somewhat pointed at the beak, length 1/4th of an inch, width nearly the same. Clearly marked lines of growth. Close to this shell there is an impression, probably of the other valve, but not so well preserved.

Locality, Outerside. Woodwardian Museum. I have named this shell after Miss C. M. Dale, by whom it was presented to the Museum.

Lingula Bannerdalii.—Fig. No. 5. Shell almost circular in shape and very flat, about 1/4th of an inch in diameter.

Portions of the delicate silicious shell are well preserved, and show concentric lines of growth.

Locality, Bannerdale, about one and a half miles N.E. of Blencathra summit. Carlisle Museum (Harkness Collection).

Lingula Harknessi.—Fig. No. 6. This is the ventral valve of a very beautiful little Lingula, broadly ovate in shape, rather gibbous, beak accuminate, front obtusely rounded. Fine concentric lines of growth discernible.

Length 3/16ths and width 1/8th of an inch.

This shell partly overlies another, probably the dorsal valve, and close to these are both valves of another individual, apparently a *Lingula Brevis*, but not so well preserved.

Locality, Outerside. Carlisle Museum (Harkness Collection).

Lingula Howardii.—Fig. No. 7. Shell broadly ovate, well rounded in front, tapering posteriorly towards the sharply pointed beak, shows fine concentric lines of growth. Posterior side convex, flattened towards the front, with a distinctly flattened rim nearly all round the margin of the valve. The beak and posterior portion of the shell are in a good state of preservation, being bright and black, but the surface of the middle and base have been partly worn away.

Length 9/20ths and width 7/20ths of an inch.

Locality, Bassenthwaite Sand Beds, near Ravenstone. British Museum (Natural History), Cromwell Road, S. W. Postlethwaite Collection, Reg. 16365.

Miss Howard (now Mrs. Leybourne Popham) was living at Ravenstone, and was present when this shell was found by the author, therefore, it has been named after her.

Lingula Derwentii.—Fig. No. 8. Oblong, sub-pentagonal, sides slightly rounded, tapering posteriorly towards the acuminate beak; front nearly straight, but slightly depressed in the middle, a narrow flattened rim extends along the sides and base. Extremely fine lines of growth are visible on the front and sides.

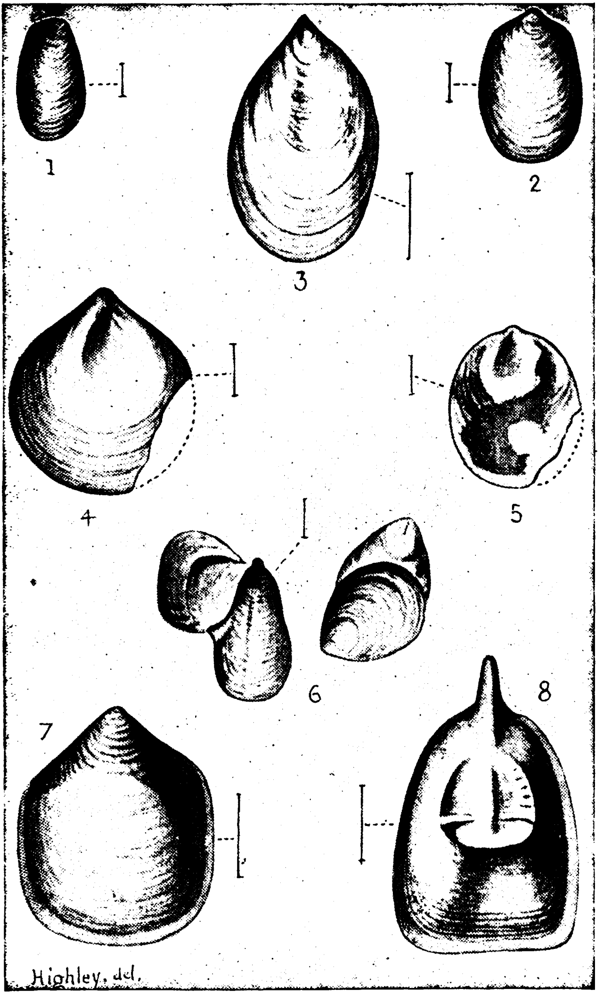
Length 1/4th, width 3/16ths of an inch.

This specimen represents a cast of the interior of the ventral valve of a very beautiful Lingula, which is named *Lingula Derwentii*, after the author's son, Derwent, who assisted and took part in many fossil hunting expeditions. The unusually large muscular impression is well preserved, and attached to the beak there is a portion of the peduncle, in an excellent state of preservation, and nearly 1/8th of an inch in length. This shell was submitted to the late Thomas Davidson, with other specimens, and he pronounced it to be a new species of Lingula. It occurs in the midst of a number of specimens of Didymograptus patulus and Caryocaris Wrightii, which are fossilized on the same slab of slate.

Locality, Randel Crag. British Museum (Natural History), Postlethwaite Collection, Reg. 16367.

Lingula, sp. probably *Lingula Brevis.*—Fig. No. 9. Shell elongated oval, nearly 1/8th of an inch in length and 1/16th of an inch in width, rounded in front, sharply pointed at the beak. Lines of growth discernible. Specimen poorly preserved.

Plate IV.



Locality, East of Dodd Wood, near Keswick. Woodwardian Museum.

Lingula Marrii.—Fig. No. 10. Shell small, ovately trigonal, convex, well rounded in front, beak obtusely pointed; marked by concentric lines of growth, every fourth or fifth being more pronounced than the intervening ones. On one side there is a conspicuous angle, enclosing a slightly concave area. Length 1/10th of an inch.

This beautiful little shell was found by Messrs. J. E. Marr and A. Harker, at Hollows, 4½ miles south-west of Keswick; they obtained it from the hardened Skiddaw Slate, close to its junction with the volcanic rocks of the Borrowdale Series. The shell is in an excellent state of preservation.

Woodwardian Museum.

Lingula Christophersoni.—Fig. No. 11. Shell pod-shaped, elongated, hinge line slightly concave.

Length 1 inch and 7/20ths, width 13/20ths of an inch at the widest part, and 6/20ths at the narrower end; in thickness it measures nearly 1/4th of an inch, the valves being closed.

Some portions of the outer shell have disappeared, and the surface in these parts is smooth and black, but in other parts the silicious fossilized shell remains; there are no lines of growth or marks of ornamentation visible. I have named this shell after my friend Mr. Charles Christopherson, by whom it was found.

Locality, Barf. The specimen is in Mr. Christopherson's collection.

Lingula Bonneyi.—Fig. No. 12. Shell ovate-oblong, slightly concave at the beak, more flattened towards the front, beak obtuse. Surface (interior) smooth to the naked eye, but under a lens shews fine concentric lines of growth. Exterior unknown.

Length ½ an inch, and width nearly 3/8ths of an inch.

This is a beautiful and very perfect specimen, the delicate silicious shell, with its pale blue tint, being in an excellent state of preservation. In shape it approaches very closely to *L. Brevis*, Portl., but is much larger than any known specimen of that species. This and other specimens were submitted for inspection to the late Thomas Davidson, and he pronounced it to be a new species of Lingula. This shell is named after Professor Bonney, who was with the author when it was found.

Locality, Bassenthwaite Sand Beds. British Museum (Natural History), Postlethwaite Collection. Reg. 16366.

Lingula Hoarii.—Fig. No. 13. Shell somewhat imperfect in outline, but when complete, must have been almost a perfect oval in shape, it measures 6/10ths of an inch in length and 3/10ths of an inch in width; well rounded towards the pointed, projecting beak, but more flat towards the front. There is a broad flattened rim extending right round the shell, except where the margin is incomplete, and the fossilized silicious shell (interior) is well preserved, and shows the lines of growth distinctly.

I have named this fossil after my friend, Miss Edith Annie Hoare, of Leamington, who has rendered valuable service in making drawings for both editions of this book.

Locality, Bassenthwaite Sand Beds, British Museum (Natural History), Postlethwaite Collection, Reg. B. 16368.

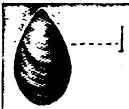
Lingula Brevis.—Fig. No. 14. This shell is almost a perfect oval in shape, slightly pointed at the beak, from which to the front there is a distinctly raised ridge, and parallel to it on each side there is a series of longitudinal lines; concentric lines of growth are also discernible.

Length 3/16ths and width 1/8th of an inch.

Locality, Outerside. Woodwardian Museum.

This shell was found by Professor Nicholson, by whom it was presented to the Museum.

Plate V.



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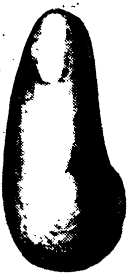

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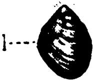

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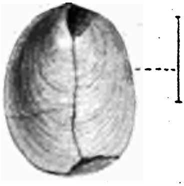

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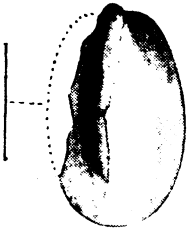

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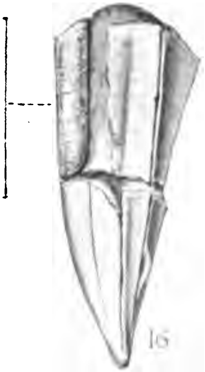

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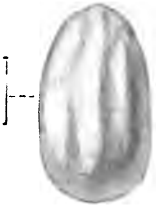

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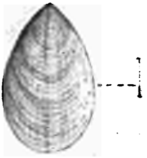

Highley, del.

On the same fragment of slate there is another shell, almost circular in shape, nearly 3/16ths of an inch in diameter. The shell is convex, almost gibbous, and shows what seem to be concentric lines of growth, but very indistinctly.

Discina ——— Fig. No. 15. Elongated oval, posterior portion partly convex, flattened towards the front.

Length 3/8ths, and width 1/4th of an inch.

Locality, Shap. Woodwardian Museum.

Class Pteropoda, Fam., Hyaleidæ. Genus Conularia.

Conularia Doveri.—Fig. No. 5. This shell was examined by the late Thomas Davidson, and was by him pronounced to be a new species of conularia; but, unfortunately, portions of the surface have been weathered away, and most of its distinctive features have been lost; the cone, however, exhibits the longitudinal divisions and finely striated surface in a fair state of preservation.

Length 7/8ths, and width 3/8ths of an inch.

Locality, Brunstock Scar, below Randel Crag. Woodwardian Museum. Dover Collection.

METAMORPHISM.

In addition to the alteration caused by lateral pressure, large areas of Skiddaw Slate have been metamorphosed by contact with, or proximity to, intrusive masses of igneous rock. The amount of alteration around the larger masses of granite, granophyre, micro-granite or quartz felsite, dolerite, diorite, &c., is very variable, while the slate around the smaller bosses and dykes is often very little altered. In many places the slate is traversed by large numbers of veins and strings of white opaque quartz, and it is generally much hardened along the sides of the veins and where the strings are numerous.

The most interesting example of metamorphism in the Skiddaw Slate area occurs around the Skiddaw Granite. There are three exposures of granite: a small one in Syning Gill, in the Glenderaterra valley, about five miles from Keswick, and two larger masses in the Caldew valley, one nearly a mile, and the other about two miles to the north. The area metamorphosed measures about six miles from east to west, and five miles or more from north to south; it is so extensive compared with the size of the exposures of granite as to leave no doubt that there is a large development of the latter beneath Skiddaw Forest, which has not been laid bare by denudation. On approaching the metamorphosed area by way of the Glenderaterra valley, the first indication of change observable in the slate is the appearance of small undeveloped crystals of chiastolite. Proceeding in the direction of the granite, the white crystals of chiastolite become larger and more numerous, measuring, where they are best developed, upwards of an inch in length. The chiastolite slate passes into a hard, massive, foliated and sonorous rock, of a darker colour, called spotted (or andalusite) schist, in which dark oblong spots take the place of crystals of chiastolite in the former, and more or less andalusite is present. This rock has been much used in the manufacture of sets of Musical Stones, for which it is peculiarly adapted. A small musical instrument of this kind may be seen in the Keswick Museum of Local Natural History. Proceeding onward, the spotted schist gradually passes into mica schist, a brownish granular, foliated rock, containing a considerable quantity of mica. This rock is in contact with the granite.

The following are analyses of the various rocks, from unaltered Skiddaw Slate to Mica Schist, according to J. Clifton Ward.

	Mean of two SkiddawSlate analyses from Red Pike and How Gill.	Chiastolite Slate from HowGill.	Spotted Schist from Skiddaw Forest	Mica Schist from junction with Granite in Syning Gill.
Silica	60·102	65·725	54·448	53·174
Alumina	17·451	14·182	23·930	24·460
Lime	1·400	1·176	1·288	1·512
Magnesia	2·144	2·342	2·379	1·946
Potash	3·232	3·261	3·010	5·037
Soda	4·099	1·981	2·086	2 930
Ferrous oxide ...	7·747	7·306	8 883	8·634
Ferric oxide	·494	trace	trace	·246
Bilsuphide of iron	...	trace	1·801	...
Phosphoric acid ...	·284	trace	·085	·128
Sulphuric acid ...	·147	·294	trace	trace
Carbonic acid ..	trace	trace	trace	trace
Carbonaceous matter	·528	2·035	·792	·717
Water	2·372	1·698	1·298	1·216
	100·000	100·000	100·000	100·000

THE VOLCANIC SERIES OF BORROWDALE.

The volcanic series of Borrowdale consists of a vast accumulation of bedded volcanic ashes interstratified in some parts with sheets of lava. It attains a thickness of from 10,000 to 12,000 feet, and occupies an area of about 400 square miles. This area is bounded on the north and north-west by Skiddaw Slate, except where it abuts against the Buttermere and Ennerdale Granophyre. The south-western boundary is formed partly of Permian Sandstone, partly of Eskdale Granite, and partly of the Skiddaw Slate of Black Combe. On the north-east it is succeeded partly by carboniferous limestone, partly by conglomerate, and partly by Skiddaw Slate, and the south-western margin is formed of Coniston Limestone. This area contains several lakes, some of the highest mountains in England, and the most varied and beautiful scenery that can be found in the British Isles.

The best section of lavas and ashes to be found in the whole area occurs on the eastern shore of Derwentwater, extending from the margin of the lake to the summit of Bleaberry Fell.* The observer should examine the first portion of the section, from the purple breccia at the base, to No. 5 lava, a little above the level of the top of Falcon Crag, ascending by way of Cat Gill, which separates that rock from Walla Crag. Above the top of No. 5 lava, there is a long stretch of swampy ground; therefore, in order to see the rest of the section with greater advantage, it will be necessary to turn due south, and walk about half a mile on the same level; then turning eastward again, ascend across the edges of the remaining beds to the summit of the mountain.

The lavas, of which there are twelve distinct sheets, are mostly very hard and compact, of a grey or bluish green colour, and often contain crystals of altered augite, garnet, and other minerals. Some of them are very much jointed and break into angular and splintery fragments. The sheets differ greatly in thickness, varying from fifteen to one hundred and fifty feet, the upper and under surface in each case being more or less vesicular and cinder-like, while the remainder is massive and compact. No. 5, however, differs considerably from the rest, being extremely vesicular throughout; but the vesicles, in this case, have been filled with quartz, calcite, and a dark-green or black earthly mineral, the product of decomposed augite. Small but beautiful specimens of agate, carnelian, and jasper are frequently obtained from this lava. It is easily recognised by its distinctive features, and may be traced a considerable distance.

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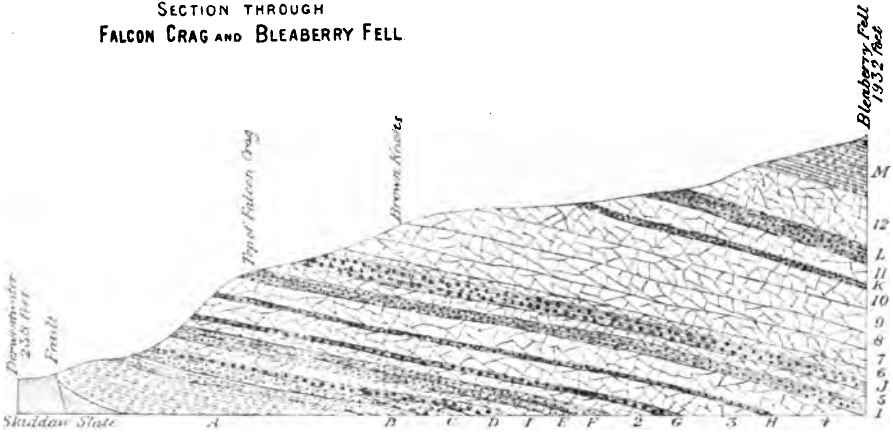
*This section is very fully described in the "Memoir of the Geology of the Northern Part of the English Lake District," by the late J. Clifton Ward.

Plate VI

SECTION THROUGH
FALCON CRAG AND BLEABERRY FELL



1 2 3 4 5 6 7 8 9 10 11 12 Lavas
A B C D E F G H I J K Ashes and Breccias

Copied from the Memoir of the Geology of the Northern part of the English Lake District by J G WARD F G S

Single sheets of lava may also be seen a little to the east of Stanah, in St. John's Vale, and at the back of Lodore Hotel, Borrowdale. The former contains numerous crystals of augite, but the latter, which is very compact, contains no crystals that are visible to the naked eye.

The following is an analysis of a typical lava, No. 6, in the Falcon Crag section:—

Silica	60·718
Alumina	14·894
Lime	6·048
Magnesia	1·909
Potash	2·354
Soda	2·843
Ferrous oxide	6·426
Ferric acid	1·405
Bisulphide of iron	·395
Phosphoric acid	·281
Sulphuric acid	·103
Carbonic acid...	1·660
Water and Carbonaceous matter	·964
	100·000

At Eycott Hill, near Berrier, about ten miles north-east of the Falcon Crag section, there is a series of lava flows, interstratified with some thin beds of ash, much smaller than the latter, but one of the lavas is the handsomest rock of its class in the Lake District. It consists of a general porphyritic base, containing dark-green spots, and large crystals of felspar (plagioclase), many of them an inch in length. For full description of this lava, see Professor Bonney's paper "On the Occurrence of a Mineral allied to Enstatite in the Ancient Lavas of Eycott Hill, Cumberland," in the *Geological Magazine* for

February, 1885; and for a description of the whole series, see J. C. Ward's paper in the *Transactions of the Royal Microscopical Society* for 1877, p. 239.

On the northern and north-western margin of the Skiddaw group of mountains (the Caldbeck range), there is another series of lava flows, interstratified with beds of ash, extending westward, as a belt, from the north-eastern side of Carrock to near Cockermouth; they attain their greatest development to the north of the eastern end of Great Lingy, where they measure about 3 miles across the strike of the beds; to the south of High Ireby, the width is 1½ miles; and westward of that point they vary from ¼ to ⅝ of a mile in width. One of the lavas, which is exposed near Whitefield Lodge, a little to the north-west of Overwater, bears a very striking resemblance to No. 5 lava of the Falcon Crag series—indeed, it can scarcely be distinguished from that rock.

There is also, on the southern margin of the volcanic area, a series of thin sheets of lava and ash, extending from Shap to a point a short distance north-west of Coniston, namely, the Shap andesites and Shap rhyolites.* The andesites consist of more or less vesicular lavas, probably made up of a succession of comparatively thin flows, interstratified with ashes and fine agglomerates.

The rhyolites consist of lavas, compact, and often of a flinty appearance, some are laminated, and others coarsely nodular, and associated with the lavas are a series of rhyolitic ashes and breccias.

The beds of ash and breccia interstratified with the lavas of the Falcon Crag section are very variable, in some the particles are so fine and the rock so compact as to be scarcely distinguishable from lava, whilst others are very coarse, containing numerous fragments of the size of walnuts, and some much larger. In colour they range from dark-green to light-grey, or sometimes purple.

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* "The Shap Granite. and the Associated Igneous and Metamorphic Rocks," by Messrs. A. Harker and J. E. Marr, Quarterly Journal of the Geological Society, London, 1891, Vol. XLVII., page 266.

Small fissures and cavities in both breccias and ashes have been filled with chlorite, epidote, quartz, calcite, and other minerals.

The ashes and breccias compose the largest portion, probably nine-tenths of the rocks of the volcanic series; they are alike, in being formed of materials that have been ejected from volcanoes, but differ with regard to the size of the fragments they contain. The ash, properly so called, varies from a rock containing fragments of the size of walnuts, which is considered a very coarse ash, to a rock formed of fine impalpable powder. Breccias are of all degrees of coarseness, from rocks formed chiefly of fragments about the size of walnuts, to those in which they measure five or six inches across; but there is one locality on the north-east of Base Brown, near Sourmilk Gill, where the breccia contains huge blocks several yards in diameter. In both coarse ashes and breccias the fragments are generally angular and unworn at the edges, but in some rare instances they are water-worn like a conglomerate. In colour the ashes and breccias vary from dark-green to light-grey, or sometimes purple. The green tints, which are very prevalent, are due to the presence of chlorite diffused through the rock, in a greater or less degree, the red and purple tints being due to hematite.

There is generally more or less stratification discernible in the ashes, shown in some cases by clearly defined bands of light and darker colour, and in others by fine and coarser materials. These alternating beds or layers of finer and coarser ash are often very irregular, some layers thinning out and others thickening; and occasionally very clear examples of false-bedding are seen amongst the finer varieties. Sometimes a single fragment of older rock of considerable size, showing all its original structure, may be seen embedded in a mass of fine ash.

The materials of which the coarser ashes and breccias are formed, consist chiefly of fragments of older ashes and lavas, but in the purple breccia, at the base of the Falcon Crag or Bleaberry Fell section, which, in that locality, is the oldest visible member of the volcanic series, there are numerous fragments of altered Skiddaw Slate. The fine ash has no doubt been formed of the same material as that which is sometimes ejected so copiously from modern volcanoes when in a state of activity, and which is merely lava reduced to powder by a succession of violent explosions of steam and gas; indeed, the ashes, breccias, and lavas of the Borrowdale Series afford abundant evidence in their structure and composition that they were derived from a similar source, and in a similar manner to the beds of recently-formed volcanic ejectamenta which may be seen surrounding the cone of an active volcano.

All the rocks of the volcanic series, as well as the underlying Skiddaw Slates, have been subjected to great lateral pressure, caused in all probability by the shrinking of the earth's crust in cooling; and this pressure, which acted in a N.E. and S.W. direction, has produced cleavage in a greater or less degree in nearly all the beds of both these formations, by causing them to expand in a direction perpendicular to that in which the pressure was applied, the particles constituting the rock being flattened and re-arranged during the process, with their longer axis in the direction in which the expansion was made. This change in the structure of the rock causes it to split readily across the old planes of stratification at a more or less oblique angle. Cleavage is very highly developed in some of the beds of ash and breccia, while in others, with which the highly-cleaved beds are in contact above and beneath, it is very imperfect. This difference appears to be due in some cases to the finer quality of the material of which the highly-cleaved beds are formed; but it is not always so, because the beds that are made up chiefly of fine materials are not uniform throughout, but have in them, here and there, portions that are very coarse, and in these coarser portions the cleavage is often as perfect as where the material is of the finest quality. From these beds of highly-cleaved ash and breccia, large quantities of beautiful and very durable roofing slate are obtained.

It was about the middle of the Ordovician Age when the great volcano of Cumberland burst into activity, and it continued discharging its lavas and ashes at intervals, spreading over a period of from three-quarters of a million to one-and-a half millions of years, according to J. C. Ward's computation. Much of the materials then thrown out have since been swept away by the various denuding agents which have acted upon our lake and mountain district since the close of the Silurian Age, but enough still remains to cover an area of about 400 square miles, and to show that its original thickness must have been from 12,000 to 15,000 feet. There were probably several centres of eruption, some of which may be deeply buried beneath materials thrown out at a later period. One or more of these centres may have been situated in the neighbourhood of Ambleside, and another at the lower end of Thirlmere, while the lavas and ashes of Eycott Hill, and the narrow strip of volcanic rock which runs through the range of Caldbeck Fells, show that others existed somewhere between Eycott Hill and High Pike. But one of the most important was no doubt close to where the town of Keswick now stands, and the position of its vent is marked by the boss of Castlehead. In the cliffs of Walla Crag and Falcon Crag, close by, there is the best development of lava flows to be found in the district, and the coarsest breccias, formed of such rough materials as would fall near the vent from which they were ejected, occur within easy distance from it; indeed, there appears to be conclusive evidence that this centre was in a state of activity, more or less, during all the earlier part of the volcanic period. The dykes, and isolated masses of diorite and dolerite which occur on Wythop Fell, Hindscarth, and Swirral Edge, in Langstrath Valley, at Hollows, Lingholm, Cockshott, and Friars' Crag, were probably fissures formed by convulsions during some of the eruptions, into which lava welled up from beneath, and gradually cooled in that position; or some of them may be necks of minor cones. The stratified condition of the ashes, together with the presence of sedimentary beds near the base of the volcanic series, and the absence of these conditions in the middle portion, indicate that volcanic action commenced beneath the waters of the Ordovician Sea, and that as successive layers of lava and ash were piled up, a gradual change took place from sub-marine conditions to those of a terrestrial and wholly sub-aërial character. Towards the close of this period the great Cumbrian volcano must have reached the size of modern Etna, or it may have exceeded it. Etna rises from the sea to a height of 10,840 feet, measures 87 English miles in circumference, and bears on its broad shoulders 200 minor cones in addition to the great central one. Some of the minor cones reach a height of 700 feet, and are in reality miniature volcanoes. This vast accumulation of volcanic materials no doubt affords a fair representation of the ancient Cumbrian volcano, as it would appear at the time when its fires were finally extinguished.

THE CROSS FELL INLIER.

On the western side of the Cross Fell range, there is an inlier of lower palæozoic rocks, extending as a narrow band of from half-a-mile to a mile in width, and about sixteen miles in length, and in a general N.W. and S.E. direction, from Limekiln Beck, a little to the north of the village of Melmerby, to a short distance south of Lycum Sike, on the south-western side of Roman Fell.

This area is bounded by two great faults, the Outer Pennine Fault on the western side, and the Escarpment Fault on the eastern side; the displacement caused by the latter brings the Lower Carboniferous rocks against Lower Palæozoic strata, whilst the former places the Lower Palæozoic rocks against the New Red Sandstone. Moreover, the inlier, between these faults, is also divided longitudinally by a third fault, the Middle Pennine Fault, by which the Higher Ordovician and Silurian strata, on the western side, are brought against the Lower Ordovician on the eastern side.

The eastern portion of the inlier is composed entirely of Skiddaw Slate, except at the northern end, where there are several dykes and intrusive masses of igneous rock. The western, or that portion of the inlier lying to the west of the Middle Pennine Fault, consists of Upper Ordovician, Lower Silurian and Carboniferous strata; the Coniston Grits, Coniston Flags, Stockdale Shales, Coniston Limestone Series, and Eycott Hill Series of volcanic rocks being present. This half of the inlier is much broken up by a set of N.W. and S.E. faults which cause repetition of some of the beds. The surface configuration of the Cross Fell Inlier, is diversified by the occurrence of a series of more or less conical hills, locally called pikes.

The sedimentary and calcareous rocks of the area have yielded fossils in great abundance.

The following is a list of species transcribed from Professor Nicholson's "Essay on the Geology of Cumberland and Westmorland:"—

HYDROZOA.
Diplograptus palmeus? Barr.

ACTINOZOA.
Petraia sub-duplicata. McCoy.
Stenopora fibrosa. Gold.

ECHINODERMATA.
Stems of Crinoids.

BRACHIOPODA.
Leptæna sericea. Sow.
Lingula ovata. McCoy.
Orthis biforata. Schlot.
,, vespertilio. Sow.
Strophomena rhomboidalis.
(vel depressa. Dalm.)
Strophomena expansa. Sow?

LAMELLIBRANCHIATA.
Modiolopsis orbicularis. Sow.
,, sp.
Pleurorhyncus sp.

GASTEROPODA.
Holopea concinna. McCoy.
Turbo sp.

HETEROPODA.
Bellerophon bilobatus. Sow.

CEPHALOPODA.
Orthoceras Brongniarti. Troost.

ANNELIDA.
Tentaculites annulatus. Schlot.

CRUSTACEA.
Ampyx mammillatus. Sars.
Agnostus trinodus. Salt.
Beyrichia complicata. Salt.
,, strangulata.
Calymene Blumenbachii. Brongn.
Homalonotus bisulcatus. Salt.
Illaenus Davisii. Salt.
Lichas Laxatus. McCoy.
Trinucleus concentricus. Eaton.

THE DRYGILL SHALES.

There is also an isolated patch of fossiliferous sedimentary slate, or shale, hemmed in amongst the volcanic rocks of the Caldbeck mountains. It is exposed in Drygill, between Carrock and High Pike, and consists, in the upper part, of light drab-coloured shale, containing a few ill-preserved brachiopods; below this is a mass of intrusive igneous rock, which decomposes when exposed to the weather. This again is underlaid by a series of dark, almost black, mudstones, crowded with fossils, which are in a fairly good state of preservation. Still descending, the dark fossiliferous shales are seen resting upon a series of volcanic rocks, consisting of breccia interstratified with bands of micro-granite or quartz-felsite. These rocks differ from the lavas and ashes of the ordinary type, in being nearly white, instead of the usual greenish grey colour. Beneath the volcanic beds there is another mass of dark fossilifeorous shales, containing large numbers of brachiopods and trilobites.

This series of shales, with their fossil contents, are fully described, together with the adjacent rocks, in a paper published in the *Geological Magazine* for August, 1887, by Professor H. A. Nicholson and J. E. Marr, F.G.S.

With regard to the stratigraphical position of the Drygill Shales, the authors of the above-mentioned paper consider that they are younger than the Upper Skiddaw Slates, and older than the Coniston Limestone, their fauna being very similar to that of the Dufton Shales, which form part of the Cross Fell Inlier.

The following is a list of species obtained from the Drygill Shales:--

Ampyx rostratus. Sars.
Calymene cambrensis. Salt.
Lichas laciniatus. Wahl.
Stygina Murchisoniæ. Murch.
Trinucleus favus. Salt.

Beyrichia complicata. Salt.
Leptæna sericea. Sow.
Obolella?
Orthis testudinaria. Dalm (abundant)

THE CONISTON LIMESTONE SERIES.

The Coniston Limestone consists of a dark-greyish blue hard and compact limestone, in which the calcareous element is very poorly developed; it is also less jointed than most rocks of its kind. The limestone is a good deal mixed up with cleaved shales, some of which are calcareous. On the eastern side of Kentmere there is a bed of contemporaneous felspathic rock of a reddish colour, interstratified with the beds of limestone and shale; some of the latter are also mixed with volcanic ashes. The whole of the beds, which are somewhat irregular, make up an average thickness of about three hundred feet.

The Coniston Limestone forms a band stretching across the Lake District, from Millom, by Broughton, Coniston, and Low Wood (near Ambleside), across the valleys of Kentmere and Long Sleddale to Wasdale Crag (near Shap), where it is partly cut off by the granite. It is again seen on the opposite side of the Shap Granite; then passes beneath the conglomerate and carboniferous rocks to re-appear once more at Keisley, where it forms part of the Cross Fell Inlier. There is also a small exposure of Coniston Limestone in the Furness District, near Dalton, where it has been brought up by anticlinal fold. In the Lake District it overlies the rocks of the volcanic series with perfect conformity, dipping to the S.S.E. at high angles. In some places it is much disturbed and shifted by faults. Although there is no want of conformity between the Ashgill Shale, the uppermost bed of the Coniston Limestone Series, and the superincumbent strata, there is complete discordance between the fossil remains found in them; therefore, it is at this point that the line of division between the Ordovician and Silurian systems is placed.*

The Coniston Limestone is no doubt the equivalent of the Bala Limestone in North Wales, the same characteristic fossils being found in each of them. Subjoined is a list of species obtained from the Coniston Series, copied from Professor Nicholson's "Essay on the Geology of Cumberland and Westmorland:"—

ACTINOZOA.

Catenipora escharoides.
(Halysites catenularius. Linn.)
Favosites crassa. McCoy.
,, polymorpha (?)
Nebulipora explanata. McCoy.
,, papillata. McCoy.
,, lens. McCoy.
Palaeopora interstincta. Wahl.
Palaeopora var. a. sub-tabulata. McCoy.
,, megastoma. McCoy.
,, petalliformis. Lonsd.
,, tabulata. Lonsd.
Petraia equisulcata. McCoy.
,, sub-duplicata. McCoy.
Sarcinula organum. Linn.
Stenopora fibroso. Gold.

Quarterly Journal, vol. 44, p. 715.

BRYOZOA.

Berenicea heterogyra. McCoy.
Ptilodictya explanata. McCoy.
,, dichotoma. Portl.
Retepora Hisingeri. McCoy.
Fenestella assimilis. Lonsd.
„ sp.

BRACHIOPODA.

Atrypa marginalis.
,, imbricata.
Leptæna minima. Sow.
,, quinquecostata.
,, sericea. Sow.
var. a. rhombica. McCoy.
„ tenuicincta McCoy.
„ transversalis. Dalm.
„ monilifera.
Lingula Davisii. McCoy.
„ ovata. McCoy.
Orthis Actoniae. Sow.
„ biforata. Schlot.
„ var. b. dentata. Pand.
„ var. c. fissicostata. McCoy.
„ calligramma. Dalm.
„ crispa. McCoy.
„ flabellulum. Sow.
„ parva. Pand (var. avellana)
„ elegantula.
Orthis Murchisoni sp.
„ Remopleurides.
„ plicata. Sow.
„ porcata. McCoy.
„ protensa. Sow.
„ vespertilio. Sow.
Pentamerus lens. Sow.
Strophomena antiquata. Sow.
„ (Leptæna) deltoidea. Conrad.
var. b. Undata. McCoy.
„ (Orthis) expansa. Sow.
„ grandis. Sow.
„ pecten. Linn.
„ rhomboidalis (Leptæna).
„ depressa. Dalm.
„ spiriferoides. McCoy.
„ corrugata. Portl.
„ deltoidea. Conrad.
Diseina rugata. Sow.

LAMELLIBRANCHIATA.

Modiolopsis Nerei. Portl.

GASTEROPODA.

Holopea concinna. McCoy
Pleurotomaria, sp.

PTEROPODA.

Conularia elongata. Portl.
Theca triangularis. Portl.

CEPHALOPODA.

Lituites cornu arietis. Sow.
Orthoceras (cycloceras) annulatum Sow.
,, filosum. Sow.
„ (cycloceras) ibex. Sow.
,, laqueatum. Hall.
Orthoceras tenui-cinctum. Portl.
,, (cycloceras sub-annulatum. Munster.
,, sub-undulatum. Portl.
,, vagans. Salt.
,, politum. McCoy

ECHINODERMATA.

Caryocystites. Davisii. Mc. Coy

ANNELIDA.

Tenaculites annulatus. Schlot.

Crustacea.

Asaphus (isotelus) Powisii. Murch.
Beyrichia strangulata. Salt
Calymene brev-capitata. Portl.
,, sub-diademata. McCoy
,, Blumenbachii. Brongn.
Cheirurus juvenis. Salt (=Ceraurus clavifrons. McCoy)
,, bi-mucronatus. Murch.
,, octo-lobatus. McCoy.?
Cybele verrucosa. Dalm.
Harpes sp
Homalonotus bi-sulcatus. Salt
Illænus Rosenbergi. Eichw.
,, Bowmanni?
,, Davisii. Salt
Lichas sub-propinqua. McCoy
,, sp.
Phacops (Portlockia) apiculatus. Salt
,, conophthalmus.
Ampyx tumidus. Forbes
Primitia McCoyii Jones (cythere phaseolus. McCoy)
Sphaerexochus mirus.
Agnostus trinodus. Salt

IGNEOUS ROCKS.

Eskdale Granite.

This is the largest exposure of granite in the Lake District, covering an area of about thirty-five square miles. It is generally rather coarse, but in some parts fine grained, and consists of quartz, containing numerous liquid cavities, triclinic and orthoclase felspar, and dark-brown mica. The felspar is more or less impregnated with hematite, which gives a reddish tint to the rock, and that tint is more apparent on a weathered surface than where it has been recently fractured, as the hematite, when liberated from the decomposed felspar, spreads over the whole face of the rock. There is, however, a small area near Waberthwaite, where the hematite is altogether absent, and the rock being fine grained and light-grey in colour, is very like Aberdeen Granite. There are three small isolated exposures of granite which are probably connected with the Eskdale mass, namely, at the foot and at the head of Wastwater, and at Burnmoor Tarn. The two former are fine grained, and the last rather coarse, but all have the reddish tint which characterises the Eskdale Granite.

The following is an analysis of Eskdale Granite :—

Silica	73·573
Alumina	13·750
Lime	1·064
Magnesia	·396
Potash	3·512
Soda	4·315
Ferrous oxide	2·103
Ferric oxide	·615
Phosphoric acid	·012
Sulphuric acid	—
Carbonic Acid	trace
Carbonaceous matter and Water	·660
	100·000

SHAP GRANITE.

On the opposite margin of the Lake Country there is a much smaller but more interesting exposure of granite. Its lithological character, its occurrence at the junction of the Coniston Limestone with the Volcanic Series, and the conclusive evidence it affords of the action of glaciers, give to it an importance that cannot be claimed on behalf of any other granitic mass in the Lake District. Where unaffected by metamorphic action, the Shap Granite is one of the most beautiful rocks in the British Isles ; the base consists of grains of white felspar and crystalline quartz, intermixed with numerous grains and crystals of black mica, and large oblong crystals of pink felspar (orthoclase). The latter are often of gigantic size, and form the distinguishing feature of the granite. It is admirably suited for ornamental work, but when used in the rough state for building purposes it does not appear to advantage.

The granite is greatly metamorphosed where it comes into contact with the surrounding rocks, the latter also being much altered. To the west of Wasdale Crag, near Scale Head Farm, it may be seen in contact with the Coniston Limestone, and it is here altered to a distance of fifty yards from the junction. Advancing towards the junction, the granite gradually becomes close grained, and the large crystals of pink felspar disappear; further on it passes into a compact pink felstone, and this in turn is changed into a greyish crystalline rock which is in contact with the limestone. The latter retains its bedded structure, but is altered, in some places, into a crystalline marble, and in others into a granular rock composed of alternating bands of white carbonate of lime and brown felspar, the heat of the granite when erupted having separated and altered the constitutents of the limestone. The calcareous shales, which overlie the limestone at this point, are also greatly altered. On the southern side of Harrop Pike, where the granite comes into contact with the uppermost beds of the Volcanic Series, the latter are changed from bedded ash into a finely foliated rock arranged in alternating bands of pink and white.

The surface of the granite has been rounded and grooved by glacial action, and countless numbers of fragments, both large and small, have been borne away by moving ice, and distributed over the whole country to the south and east of the parent mass. Some of the fragments have been conveyed across the Pennine Chain to a distance of sixty miles from their original home, the distinctive character of the rock rendering them easily recognisable wherever they may be found.

SKIDDAW GRANITE.

A small mass of Skiddaw Granite is exposed in Syning Gill, near the base of Blencathra, and a larger mass at the upper end of the valley of the Caldew; there is also a third exposure a little lower down the course of that river, which is connected, on its northern margin, with the igneous rocks of Carrock Fell. The granite is composed of white opaque felspar (both orthoclase and triclinic), dark-brown or black mica, and quartz containing numerous liquid cavities; also a few grains of magnetite. In some parts it is fine grained, and in others coarsely crystalline. The more or less clear quartz, dark mica, and opaque white or sometimes cream-coloured felspar, produce a sufficiently striking and rather pretty effect when the rock is polished.

The largest exposure measures about a mile in length and half-a-mile in width. There is little or no appearance of change in the granite at or near the junction, but the overlying slate is extensively altered (see page 27). The granite in Syning Gill is very hard and compact, but in the two northern exposures it is soft and crumbling; they are all alike, however, in crystalline structure and mineral composition, and the several exposures doubtless form portions of a continuous mass, which extends over a large area, at a very short distance beneath the surface. If denudation had made a little less progress, the Skiddaw Granite would still have been buried, and its presence indicated only by metamorphism in the superincumbent slate.

The following is an analysis of this granite :—

Silica	75·223
Alumina	11·140
Lime	1·624
Magnesia	1·081
Potash	4·516

Soda	3·996
Ferrous oxide	1·771
Ferric oxide	trace
Phosphoric acid	·149
Sulphuric acid	trace
Carbonic acid	trace
Carbonaceous matter	·103
Water	·397
	100·000

BUTTERMERE AND ENNERDALE GRANOPHYRE.

This mass of granophyre occupies a large area, extending from Buttermere on the north to Wastwater on the south, a distance of nine miles, and for a great part of the distance forms the boundary between the Skiddaw Slate and the Volcanic Series. The granophyre is generally of a pale red colour, sometimes changing to dark-grey, and is fairly uniform in appearance. It consists of pink felspar (plagioclase and orthoclase), transparent quartz, dark hornblende, chlorite, and a little mica. Usually it is very hard, but on the mountain tops it crumbles into a coarse sand. The following is an analysis of a specimen of this rock from near Scale Force :—

Silica	71·442
Alumina	15·340
Lime	1·064
Magnesia	·720
Potash	4·439
Soda	3·951
Ferrous oxide	1·107
Ferric oxide	1·230
Phosphoric acid	·118
Sulphuric acid	trace
Carbonic acid	trace
Carbonaceous matter and Water	·589
	100·000

ST. JOHN'S MICROGRANITE OR QUARTZ FELSITE.

This rock occurs in two masses, occupying both sides of the lower end of the Vale of St. John. Each of these masses measures about a mile from north to south, and from half to three-quarters of a mile from east to west; they are each bounded on the east, west, and north by Skiddaw Slate, and on the south by the Volcanic Series. It is probable that the great fault, which separates the two formations, may have been the channel through which the materials of these masses, as well as the Buttermere and Ennerdale Granophyre, welled up from beneath in a molten state; not to the surface, but into huge caverns formed in the Skiddaw Slate by folding and crumpling. caused in all probability by the earth movements which produced the fault. The liquid cavities in the quartz show that the microgranite solidified under great pressure, and at a considerable depth beneath the surface.

The microgranite consists of orthoclase, microline and oligoclase felspar, quartz, calcite, and schorl, also some epidote and serpentine; part of the last named has probably replaced mica. The colour is generally grey, but in some places it assumes a reddish tint. The rock is generally well jointed, as at Shundraw and Threlkeld quarries, and frequently contains large fragments that are much altered. It may be examined under the most favourable conditions at the latter quarry, where large quantities have been excavated for road metal, setts, and kerbing, for which purposes it is well adapted; and it may also be seen in contact with the Skiddaw Slate at the eastern end of the quarry. Close to the junction, the microgranite is slightly altered in appearance, and becomes more brittle; the slate is also hardened, and contains irony spots. The microgranite in the quarry is of a light-grey colour, with occasional patches of a reddish tint. The crystals of quartz and felspar are enclosed in a felsitic base, and there are occasionally fan-shaped crystals of schorl. The oligoclase, which is much altered, is of a yellowish green colour. Crystals of blende and galena have been found in some of the joints. The following is an analysis of this rock :—

Silica	67·180
Alumina	16·650
Lime	2·352
Magnesia	1·549
Potash	2·914
Soda	4·032
Ferrous oxide	2·151
Ferric oxide	·559
Phosphoric acid	·179
Sulphuric acid	trace
Carbonic acid	·885
Carbonaceous matter	·797
Water	·752
	100·000

ARMBOTH DYKE.

This dyke is a microgranite, being precisely the same in chemical composition as the St. John's Microgranite or Quartz Felsite. It is a very beautiful rock, consisting of a dull red felsitic base, studded with numerous crystals of pink felspar and transparent quartz, also a little serpentine, and occasional grains of green mica. The dyke is from twenty to thirty feet in width, and extends in a N.N.W. and S.S.E. direction across Armboth Fell, where it may be traced for a distance of about one and a half miles. It appears again on the opposite side of the valley, near the seventh milestone on the road from Keswick to Ambleside, and extends in a S.E. direction beyond the crest of Helvellyn.

HORNBLENDE PICRITE OF LITTLE KNOT.

This is a coarsely crystalline rock of a dark olive-green colour; it is largely composed of hornblende, but the following minerals are also present in small quantities, namely—quartz, felspar (plagioclase), iron peroxide, epidote, apatite, olivine, and calcite. It occurs in an oblong mass, about 1,800 feet in length by 120 feet in width, and extends from Little Knot, at the northern end of Longside, down nearly to the bottom of Barkbeth Dale. There are some gigantic blocks of this rock on the opposite side of the ravine, nearly on a level with the main mass at Little Knot, but they rest on Skiddaw Slate, and do not appear to be connected with any body of picrite *in situ.* The slate near the picrite is a good deal altered.

THE DIORITIC PICRITE OF WHITE HAUSE AND GREAT COCKUP.

This rock is very nearly allied to the hornblende picrite of Little Knot; it is exposed on both sides of Hause Gill, which separates White Hause from Great Cockup. The exposure on the former measures from 36 to 45 feet square, that on the latter mountain being somewhat smaller. The two masses are about one-third of a mile apart, and are doubtless connected beneath the till which forms the floor of the little valley.

The dioritic picrite is a coarsely crystalline rock of a dark olive-green colour, consisting of several varieties of hornblende, also quartz, felspar, calcite, serpentine, iron peroxide, and probably a little apatite, ilmenite, and viridite. It is somewhat difficult to prove from microscopic examination that olivine has been a constituent of the rock, as it is much altered; but Professor Bonney thinks it is represented by some of the serpentinous mineral, and that the rock may be regarded as one of the transitional forms between normal picrite and normal diorite.

The amount of alteration observable in the rocks surrounding the dioritic picrite, as the result of contact with it while in a molten state and during the process of cooling, is larger than that observable at Little Knot.

SALE FELL MINETTE.

At the summit of Sale Fell, there is a minute patch of very beautiful rock. It consists of a pink crystalline felspathic base, in which there are numerous crystals of dark-green mica. The base is chiefly composed of orthoclase, but some triclinic felspar [is also present. There is no quartz visible to the naked eye, but small crystals may be detected under the microscope. There is also a little hornblende present. The rock is very hard and tough, and in lithological character is unlike any other rock in the neighbourhood.

IGNEOUS ROCKS OF CARROCK FELL.

On Carrock and the adjoining mountain, Great Lingy, there is a series of igneous rocks, consisting of (*a*) granophyre, (*b*) gabbro, and (*c*) diabase. The granophyre is a coarsely grained rock, very hard and tough, and of a pale red or brownish-grey colour, with a number of greenish crystals, which show a spherulitic structure, scattered through it. The gabbro is generally coarsely crystalline, but sometimes fine-grained. The base of this rock consists of large crystals of opaque white felspar (plagioclase) and interstitial quartz; and through it are scattered crystals of dark olive-green diallage, which is very nearly allied to hypersthene; also occasional grains of magnetite and apatite. Large blocks of lava of the Eycott Hill series are here and there enclosed in the gabbro. The diabase is also coarsely crystalline, of a dark green colour, and in some parts shows distinct lines of bedding.

THE IGNEOUS ROCKS OF SEATOLLER FELL.

On Seatoller Fell, Borrowdale, there is a dyke of diorite lying between two masses of intrusive diabase. The masses of diabase together measure about three-quarters of a mile in length by about a quarter of a mile in width. The rock is very compact, and of a dark-blue colour; it consists of a felsitic base, in which there are crystals of triclinic felspar, quartz, augite, and some magnetite. The diorite, which is much altered, is made up of numerous small crystals of felspar, hornblende, magnetite and chlorite. The dyke is about one-third of a mile in length, and forty or fifty feet in width. It is in connection with these masses of blue diabase, the dyke of diorite, and the adjoining ash rocks, that the rich deposits of graphite have been found. The ash all round the igneous rocks is much altered.

GARNET-BEARING ROCKS OF THE VOLCANIC SERIES.

These rocks attain their greatest development beneath the banded ashes of Scawfell and the adjoining mountains, and extend in a narrow band, from one-and-a-half miles to two miles in width, from near the head of Wastwater to Dunmail Raise, and in a narrower band, from Scawfell to the upper part of Langdale valley. They also occur in another area around and to the west and north-west of Haweswater. The rock is generally of a greenish or greyish colour, with a compact base in which crystals of felspar and augite occur; in some places it appears to pass into ash, and occasionally into breccia. The garnets, in some localities are small, and very sparsely scattered, and in others they are numerous and of considerable size. Formerly these rocks were regarded as contemporaneous lavas and ashes, but Messrs. Marr and Harker consider that the evidence, on the whole, points to the intrusive character of the most of them.*

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* Proceedings Geological Association, Vol. XVI., page 477.

CASTLEHEAD, KESWICK.

This mass of dolerite, although not remarkable for beauty, is in some respects one of the most interesting of the igneous rocks in the neighbourhood, as it probably represents the last expiring effort of the great Cumbrian volcano, which on that occasion succeeded only in raising the lava part of the way up the vent, where it solidified, and at some period, long afterwards, became exposed through the removal of the cone by denudation.

The rock is highly crystalline, and is composed of augite and pale-coloured felspar, with crystals of a soft dark green pseudomorphic mineral, in which both serpentine and chlorite are present. Small veins of quartz and calcite occur in it; also flakes of brown mica, and some magnetite. Nearly all the mineral constituents of this rock have been either replaced or altered.

In addition to those already described, there are small bosses and dykes of igneous rock on Skiddaw Dodd, Seathwaite How (near Embleton), Wythop Fell, Hindscarth, Burtness Combe (near Buttermere) Swirral Edge, Helvellyn, Langstrath in Borrowdale, near Troutbeck, and on Matterdale Common.

STOCKDALE SHALES (LOWER SILURIAN).

On the south-east, the Coniston Limestone Series is succeeded conformably by a belt of highly fossiliferous shales measuring from 250 to 400 feet in thickness, which were variously named by the earlier workers, "Coniston Flags," "Coniston Mudstones," and "Graptolitic Mudstones," but since the Geological Survey Memoir, by Messrs. W. T. Aveline and T. McK. Hughes, was issued in 1872, they have been known by the name of "Stockdale Shales," that name having been given to them by the authors of the Memoir, because they attain their fullest development in the course of Stockdale Beck and its tributaries. In May, 1888, a very able and exhaustive Paper, on these shales and their fossil contents, was read before the Geological Society by Professor Nicholson and Mr. J. E Marr, F.G.S. (*Quarterly Journal*, vol. 44, p. 654), and in this Paper the beds were classified as follows:—

Stockdale Shale Series	Upper Browgill Stage.	
	Lower	do.
	Upper Skelgill Stage.	
	Middle	do.
	Lower	do.

These stages are futher subdivided into a series of zones, and described, with lists of the fossils they contain. The Browgill Beds are well exposed in Browgill, a tributary of Stockdale Beck, and a splendid section of the Skelgill Beds may be seen on the banks of a small rivulet, which runs into Windermere Lake, a few yards south of Low Wood Hotel. On the Ordnance Maps the rivulet is named Holbeck, but it is better known amongst geologists by the name of Skelgill Beck (so called from the farm of High Skelgill, near its bank).

The belt of Stockdale Shales, measured across the strike of the beds does not average more than from one to one and a half miles in breadth, and extends from the Duddon estuary to Shap Fells, where it disappears beneath the basement bed of the carboniferous series. It re-appears again, however, near Knock, in Westmorland, as part of the Cross Fell Inlier. There is also another exposure of the Stockdale Shales on the eastern side of the Duddon estuary, near Dalton-in-Furness.* The shales vary in colour from pale-green to black; some of the beds contain considerable quantities of iron pyrites, and the rock is much stained owing to the decomposition of the mineral. The more highly fossiliferous beds are crowded with organic remains, while in others they are comparatively scarce, and some are quite barren.

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*Associated with the inlier of Coniston Limestone and Stockdale Shales near Dalton, there is a small patch of Skiddaw Slate, and a little to the north a narrow strip of altered volcanic ash. The amount of displacement required to place these rocks, especially the former, on a level with the Stockdale Shales, must have been very great indeed, probably from 12,000 to 14,000 feet.

The following is a list of fossils obtained from the Stockdale Shales, transcribed from the Paper by Professor Nicholson and Mr. Marr:—

Monograptus leptotheca. Lapw.
„ griestonensis. Nicol.
„ proteus. Barr
„ crassus. Lapw.
„ lobiferus. McCoy
„ broughtonensis. Nich.
„ Sandersoni. Lapw.
„ revolutus. Kurck.
„ attenuatus. Hopk.
„ tenuis. Portl.
„ fimbriatus. Nich.
„ gregarius. Lapw.
„ triangulatus. Harkn.
„ cyphus. Lapw.
„ argenteus. Nich.
, Nicoli. Harkn.
„ Clingani Carr
„ crenularis. Lapw.
„ convolutus. His.
„ involutus. Lapw.
„ argutus. Lapw.
„ Hisingeri. Carr
„ communis. Lapw.
„ spinigerus. Nich.
„ distans. Portl.
„ jaculum. Lapw.
„ crispus. Lapw.
„ exiguus. Nich.
„ pandus. Lapw.
„ discus. Tornq.
„ discretus. Nich.
„ rectus?
„ turriculatus. Barr.
„ concinnus. Lapw.
Dimorphograptus confertus. Nich.
„ elongatus. Lapw.
„ Swanstoni. Lapw.
Rastrites peregrinus. Barr.
„ hybridus. Lapw.
„ urceolus. Richter.
„ gemmatus. Barr.
„ distans. Lapw.
„ maximus. Carr
Retiolites perlatus. Nich.
„ Geinitzianus. Barr.
„ cf. macilentus. Tornq.

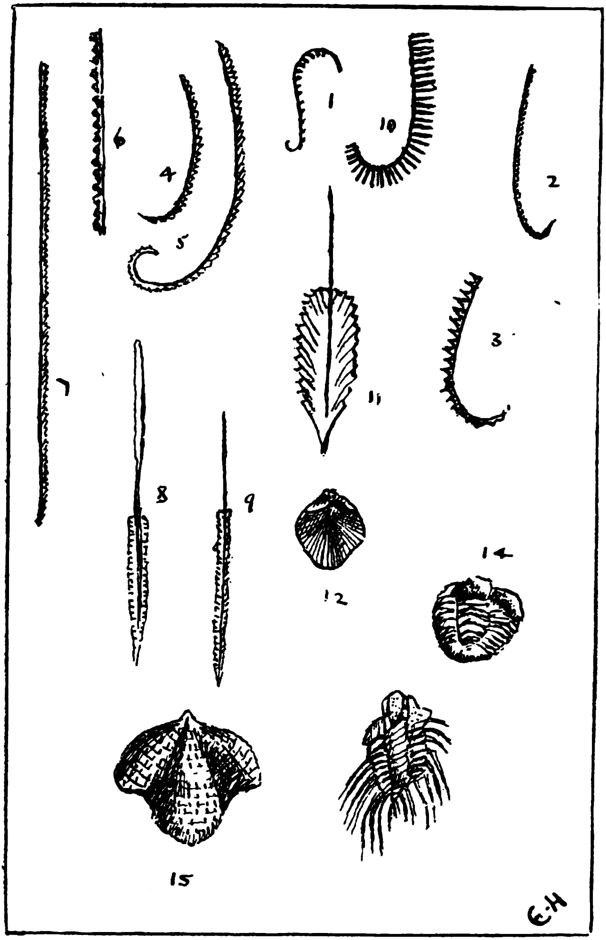
Diplograptus sinuatus. Nich.
,, longissimus. Kurck.
,, vesiculosus. Nich.
,, modestus. Lapw.
,, Hughesii. Nich.
,, tamariscus. Nich.
,, acuminatus.
Petalograptus ovatus. Barr.
,, var. tenuis. Barr.
,, ovato-elongatus. Kurck
,, cometa. Gein.
„ folium. His
,, palmeus. Barr.
Climacograptus normalis. Lapw.
,, minutus. Carr
Cyrtograptus Grayæ. Lapw
,, spiralis. Gein.
Discinocaris Brouniana. Woodw.
,, gigas. Woodw.
,, n. sp.
Dawsonia campanulata. Nich.
Leptæna quinquecostata. McCoy.
,, cf. sericea. Sow.
Atrypa flexuosa, n. sp.
Strophomena.
Homalonotus?
Orthoceras araneosum. Barr.
Encrinurus punctatus. Wahl.
,, var. arenaceus Salt.
Acidaspis erinaceus, n. sp.
Favosites mullochensis. Nich. & Eth.
Phacops elegans. Bœck and Sars
,, var. glaber
,. mucronatus
Cheirurus bimucronatus. Murch.
var. acanthodes. var. nov.
,, moroides, n. sp.
Harpes angustus, n. sp.
,, judex, n. sp.
Calymene Blumenbachii. Brongn.?
Whitfieldia tumida. Dalm?
Peltocaris aptychoides. Salt
Aptychopsis Lapworthi. Woodw.
Ampyx aloniensis, n. sp.
Proetus brachypygus, n. sp.
Illænus Bowmanni. Salt

The graptolites in this list are altogether different from those obtained from the Skiddaw Slates, the many-branched forms, and, indeed, nearly every species found in the older rocks having disappeared in the interval between the deposition of the upper beds of Skiddaw Slate and the lower beds of the Stockdale Series.

EXPLANATION OF PLATE VII.

Fig. 1—Monograptus crispus.
,, 2— ,, exiguus.
,, 3— ,, triangulatus.
,, 4— ,, gregarius.
,, 5— ,, cyphus.
,, 6— ,, lobiferus.
,, 7— ,, jaculum.
,, 8—Diplograptus vesiculosus.
,, 9—Climacograptus normalis.
,, 10—Rastrites perigrinus.
,, 11—Petalograptus folium.
,, 12—Orthis elegantula.
,, 13—Acidaspus erinaceus.
,, 14—Protëus brachypygus.
,, 15—Atrypa flexuosa.

Plate VII.



CONISTON FLAGS AND GRITS.

LOWER SILURIAN (WENLOCK SERIES).

The Stockdale Shales are succeeded on the south-east by the Coniston Flags and Grits, which attain a total thickness of about 6,800 feet, as stated by Messrs. W. T. Aveline and T. McK. Hughes, namely, 2,800 feet of flags and lower grit beds, and 4,000 feet of upper grits, the beds being somewhat thinner on the eastern side of the district. The flags and grits occupy two separate areas—one where they succeed the Stockdale Shales and older rocks, in regular order, between the Duddon estuary on the south-west and Shap Fells on the north-east; and the other where they occupy the high ground around Howgill and Langdale Fells on the east side of the Lune, and on Grayrigg Common and Whinfell Beacon on the west side of the Lune. There is also a considerable area of flags and grits in the northern part of Furness.

The flags consist of dark-blue laminated sandy mudstones, which split into moderately thin flags, where the cleavage is well developed. The lower part of the flags has yielded a considerable quantity of graptolites, trilobites, and encrinites, but in the upper beds fossils are somewhat scarce.

The grits consist of thick beds of tough grit or sandstone, interstratified with flaggy beds. They, too, have yielded a considerable number of fossils, one bed near the base being remarkably prolific.

The following is a list of fossils obtained from the Coniston Grits, transcribed from the Memoir of the Geological Survey, by Messrs. W. T. Aveline and T. McK. Hughes :—

A small Bryozoon.
Favosites aspera. d'Orb.
Halysites catenularius. Linn.
Monticulipora, sp.
Petraia, sp
Cyathocrinus, sp.
Cornulites serpularius. Schlot
Tentaculites tenuis Sow.
Beyrichia Klœdeni. McCoy.
Phacops, sp.
Chonetes lata. V. Buch
Orthis elegantula. Dalm.
Actinocrinus pulcher.
Acidaspis, n. sp. Salt.
Ceratioraris robustus.
Cyrtograptus Murchisoni. Carr.
Athyris.

Meristella ?
Orthis Lewisii, var. Hughesii. Dav.
Pterinea tenuistriata.
Rhynchonella navicula. Sow.
„ nucula. Sow.
Spirifera crispa. Hesing.
,, elevata. Dalm.
Cardiola interrupta. Sow.
Holopella gregaria. Sow.
Bellerophon, sp.
Lituites giganteus.
Orthoceras ibex.
„ Ludense.
,, primævum.
,, sub-undulatum
Encrinites.

BANNISDALE SLATES AND KIRKBY MOOR FLAGS.

Upper Silurian (Ludlow Series).

The Coniston Flags and Grits are succeeded on the south and south-east by rocks of the Ludlow formation, comprising beds belonging to both the lower and upper divisions of that series, namely, the Bannisdale Slates and the Kirkby Moor Flags. They attain their greatest development between Kendal and Kirkby Lonsdale, where they measure about eleven miles across the outcrop of the beds. This area is bounded on the north by the Coniston Grits, on the east by the Lune Valley Fault, and on the south and west by carboniferous limestone. The Upper Ludlow Rocks re-appear from beneath the limestone in a narrow strip on the eastern side of Kendal Fell, and there is an outlier of the same rock, extending in a narrow band from about three-quarters of a mile north-west of Staveley to Borrow Beck, near Hollowgate. The Bannisdale Slates (Lower Ludlow) consist chiefly of sandy mudstones, interstratified with beds of grit and thin bands of hard sandstone. Rough and inferior slates are sometimes obtained from these beds, but they rarely yield even a tolerable quality. The mudstones are, however, extensively quarried for paving and building stone, and for rough slabs. The

Kirkby Moor Flags (Upper Ludlow) consist chiefly of thick beds of hard concretionary sandstone, interstratified with thinner beds of fine-grained micaceous sandstone of a flaggy nature.

Fossils are scarce in the Bannisdale Slates, but are very plentiful in the Kirkby Moor Flags. Subjoined is a list of species obtained from them, transcribed from Professor Nicholson's "Essay on the Geology of Cumberland and Westmorland":—

PROTOZOA.

Spongarium equi-striatum. McCoy.
,, interlineatum. McCoy.
Spongarium interruptum. McCoy.

ACTINOZOA.

Catenipora escharoides.
Cyathaxonia Siluriensis. McCoy.
Nebulipora papillata. McCoy.
Stenopora fibrosa. Gold.
var. b. regularis. McCoy.

BRACHIOPODA.

Chonetes lata. Von. Buch.
Discina rugata. Sow.
,, striata. Sow.
Lingula cornea. Sow.
Orthis lineata. Sow.
Rhynconella navicula. Sow.
,, nucula. Sow.
Siphonotreta anglica. Morris.
Strophomena filosa. Sow.

LAMELLIBRANCHIATA.

Anodontopsis angustifrons. McCoy.
,, bulla. McCoy.
,, securiformis. McCoy.
Arca (?) primitiva. Phill
Avicula Danbyi. McCoy.
Ctenodonta (nucula) anglica. d'Orb.
,, (arca) Edmondiiformis. McCoy.
Cucullella coarctata. Phill.
,, ovata. Sow.
Grammysia cingulata. His.
,, var. b. triangulata. McCoy.
,, extrasulcata. Salt.
,, (mya) rotundata. McCoy
Modiolopsis complanata. Sow.
,, (orthonota) solenoides. Sow.
Orthonota amygdalina. Sow.
,, angulifera. McCoy.
,, globulosa. McCoy.
,, semi-sulcata. Sow.
,, truncata. McCoy.
,, undata. Sow.
Pterinea Boydii. Conr.
,, demissa. Conr.
,, lineata. Gold.
,, pleuroptera. Conr.
,, retroflexa. Wahl.
,, var naviformis.
,, sub-falcata. Conr.
,, tenuistriata. McCoy.
Sanguinolites decipiens. McCoy.
Tellinites affinis. McCoy.

GASTEROPODA.

Cyclonema (litorina) octavia. d'Orb.
Holopella cancellata. Sow.
,, gregarea. Sow.
,, intermedia. McCoy.
Murchisonia (litorina) corallii. Sow.
,, torquata. McCoy.
Naticopsis glaucinoides. Sow.
Pleurotomaria crenulata. McCoy.

HETEROPODA.

Bellerophon expansus. Sow.
Conularia cancellata. Sandberger.
Conularia subtilis. Salt.
Theca Forbesii. Sharp.

CEPHALOPODA.

Lituites (hortolus) ibex Sow.
Orthoceras anuglatum. Phill.
,, baculiforme. Salt.
,, bullatum. Sow.
,, dimidiatum. Sow.
,, (cycloceras) ibex. Sow.
,, imbricatum. Wahl.
,, laqueatum. Hall.
Orthoceras (cycloceras) sub-annulatum. Münst.
,, Sub-undulatum. Portl.
,, (cycloceras) tenui-annulatum. McCoy.
,, tenui-cinctum. Portl.
,, (cycloceras) tracheale. Sow.

ECHINODERMATA.

Ichthyocrinus pyriformis. Phill.
Palaeaster (uraster) hirudo. Forbes
,, (uraster) primaevas. Forbes
,, (uraster) Ruthveni Forbes.
Protaster Sedgwickii. Forbes.
Taxocrinus Orbigyni. McCoy.
Tetragonis Danbyi. McCoy.

ANNELIDA.

Cornulites serpularius. Schlot.
Serpulites disper. Salt.
Tentaculites tenuis. Sow.
Trachyderma squamosum. Phill.

CRUSTACEA.

Beyrichia Klödeni. McCoy.
Calymene tuberculosa. Salt.
Ceratiocaris elliptica. McCoy.
,, inornata. McCoy.
,, solenoides. McCoy.
Eurypterus cephalaspis. Salt.
Homalonotus Knightii. König.
Phacops caudatus. Brongn.
,, var minor. McCoy.
Proetus (Forbesia) latifrons. McCoy.

CARBONIFEROUS ROCKS.

The Lake District is almost surrounded by carboniferous strata, extending in a continuous belt from Egremont on the west, around the northern and eastern margin, to Ingleton on the south-east, thence in detached patches to Silecroft, on the western side of the Duddon estuary; the remaining twenty miles being the only important break in the circle, and in that portion it is probably continuous beneath the new red rock.

The rocks which compose this belt of carboniferous strata may be grouped under the following divisions, in descending order:—

Carboniferous Series
- Coal Measures.
- Millstone Grit.
- Yoredale Series.
- Carboniferous Limestone Series.
- Lower Limestone Shale Series.
- Basement Conglomerate.

These divisions are not continuous, and they vary very much in their development at different points. In the Whitehaven district, the whole series has an ascertained thickness of 3,078 feet, as stated by Mr. J. D. Kendall, F.G.S., namely, coal measures 2,078 feet, millstone grit 155 feet, Yoredale series 540 feet, carboniferous limestone 228 feet, and lower limestone shale 77 feet. In Furness there is, according to the same author, an ascertained thickness of over 2,464 feet, as follows:—Yoredale series 744 feet, carboniferous limestone 950 feet, lower limestone shales 720 feet, and basement conglomerate about 50 feet, the coal measures and millstone grit being absent. And at Blencow, about four miles west of Penrith, the Yoredale series measures 525 feet, carboniferous limestone 135 feet, and the basement conglomerate, although its actual depth at this point has not been proved, is no doubt of great thickness, seeing that at Mell Fell, five miles west of Blencow, it measures about 2,500 feet, making a total in this area of 3,160 feet, the millstone grit and coal measures not being represented.

The conglomerate was formerly classed as Old Red Sandstone, but it has been shown by J. Clifton Ward, F.G.S., and other workers, to be the basement bed of the carboniferous series. It attains an abnormal development between Mell Fell and Pooley Bridge, where it measures about three-and-a-half miles across the strike of the beds, the total thickness being about 2,500 feet as before stated. The rock consists of a matrix of indurated clay or sand, in which pebbles of all sizes are embedded, and occasionally large angular blocks, as much as three feet in length. A large proportion of the included pebbles are composed of gritty and micaceous sandstone like the Ludlow Rocks, but there are also some of ash, trap, and altered Skiddaw Slate. At Shap, the conglomerate measures less than twenty feet, and in Furness it is about fifty feet in thickness.

The various beds of limestone, sandstone, and shale that were piled upon the conglomerate, and that now form the carboniferous series, are very persistent, extending over large areas; many of them being recognisable by their mineral character, and the position they occupy in the series.

The Lower Limestone Shales, which rest upon the basement conglomerate, are made up of a series of thick beds of dark or black shale, interstratified with thin beds of limestone and limy shale. Nearly all the shales are more or less calcareous, and most of the limestone is impure and earthy.

The Carboniferous Limestone consists of thick beds of limestone, interstratified with thin beds of shale and some sandstone. One of the beds of limestone in Furness attains a thickness of nearly 400 feet; one at Parkhead, near Caldbeck, 200 feet; and one in the Cross Fell Range, 130 feet.

The Yoredale Series consist of thick beds of black and drab-coloured shales, interstratified in the lower part with beds of limestone, and in the upper part with beds of sandstone and some limestone.

The Millstone Grit comprises all the strata between the uppermost beds of the Yoredale Series, and the base of the coal measures. It is largely made up of beds of sandstone and grit, with occasional beds of shale and some very thin seams of coal. A small quantity of coal is occasionally obtained from a thin seam in the millstone grit on the western margin of Greystoke Park.

The Coal Measures consist of the usual alternations of sandstone, grit, and shale; also, seams of coal and some thin beds of limestone. They occur in three areas on the margin of the Lake District, namely, the Cumberland, the Ingleton and Burton, and the Argill coalfields. The Cumberland coalfield stretches along the western coast, from Barrowmouth, near Whitehaven, to Maryport; and thence, trending eastward around the base of the Caldbeck mountains, to High Hall, about three miles south of Wigton. This north-eastern prolongation of the coalfield is no doubt due to two great lines of fault, both of which have a downthrow to the north-west. The southern one cuts off the carboniferous beds and brings in the coal measures along a line a little north of Plumbland, Torpenhow, and Bolton Gate, to and beyond High Hall. The northern fault extends from a point a little north of Bolton Low Houses, by Aspatria to Maryport, and forms the boundary between the coal measures and St. Bees Sandstone.

The superficial area of the Cumberland coalfield is about 100 square miles, and, where it attains its greatest vertical development, near Whitehaven, there are five workable seams of coal, varying from two to eleven feet in thickness; these, added together, give a total of about thirty feet of coal. There are also several thin seams that are too small to be worked profitably. At Whitehaven, and also at Workington, coal mining operations have been extended a considerable distance beneath the Solway, and large quantities of coal obtained therefrom. The beds are very much broken up by faults, which cause displacement varying from a few feet to twenty-five fathoms. The general dip of the beds on the coast is towards the west, at a gradient of about one in ten, but in the north-eastern portion it is towards the north-west.

The Ingleton and Burton coalfield does not exceed one-fifth of the superficial area of that in Cumberland. The coal measures are overlaid in the central portion by Permian strata, and most of the area is greatly obscured by drift. There are seams of coal measuring from one to nine feet in thickness; and these have been worked along the southern border of the area, from Black Burton eastward to the Craven fault, south of Ingleton.

The coalfield at Argill, near Brough, in Westmorland, was discovered by Mr. J. G. Goodchild, F.G.S., upwards of twenty years ago. Although very small in superficial area, there is a great thickness of coal measures, overlying 1000 feet or more of millstone grit. In the coal measures there are about twenty distinct seams of coal of good quality, eight or nine of them being not less than two feet, and one nearly eight feet in thickness. There are also several thick deposit of fire-clay.

The Carboniferous rocks, as their name indicates, are remarkable, above all other geological formations, for the profusion of fossil-vegetation they contain, but they are also rich in fossilized remains of animal life. The graptolites, which were so numerous in the Ordovician and Lower Silurian rocks, had disappeared, and trilobites were dying off, but the remains of shell-fish had largely increased, while ganoid fishes, corals, encrinites, and a higher class of amphibian mammalia had appeared, together with insects of various kinds.

Subjoined is a list of fossil plant remains transcribed from the *Quarterly Journal* of the Geological Society, vol. 59, 1903, as recorded in a valuable Paper on the "Fossil Flora of the Cumberland Coalfield," by Mr. E. A. Newell Arber, F.G.S.:—

Calamites (Eucalamites) ramosus. Art.
,, (Calamitina) approximatus. Brongt.
,, ,, varians. Sternb.
,, (Stylocalamites) Suckowi. Brongt.
,, ,, Cisti. Brongt.
Calamocladus equisetiformis. (Schl.)
Neuropteris Schenchzeri. Hoffm.
,, obliqua. (Brongt.)
,, tenuifolia. (Schl.)
,, heterophylla. Brongt.
,, gigantea. Sternb.
Mariopteris (Diplothmema) muricata (Schl.)
,, muricata. (Schl.)
,, latifolia. (Brongt.)
,, sp.
Annularia sphenophylloides. (Zenker.)
Sphenophyllum cuneifolium. (Sternb.)
Lepidodendron aculeatum. (Sternb.)
,, Wortheni. Lesq.
,, lycopodioides. Sternb.
Lepidophloios (Halonia), sp.
Lepidophyllum, sp.
Sigillaria scutellata. Brongt.
,, ovata. Sauveur.
,, lævigata. Brongt.
Stigmaria ficoides. (Sternb.)
Sphenopteris obtusiloba. Brongt.
,, furcata. Brongt.
Alethopteris Serli. Brongt.
,, decurrens. (Art.)
Cordaites principalis. (Germar.)
Cordaites, sp.
Pinnularia, sp.
Bothrodendron minutifolium. (Boulay)?
Zeilleria delicatula. (Sternb.)

PERMIAN AND TRIASSIC ROCKS
(NEW RED SERIES).

The girdle of carboniferous rocks, which almost surrounds the Lake District, is succeeded by an outer girdle of Permian and Triassic strata. These rocks cover a much larger area, but in all probability their thickness is not far in excess of the carboniferous series. On the north and north-east they extend from Maryport to a point about three miles north of Netherby, and from Bowness-on-Solway to Kirkby Stephen, being cut off on the east by the Pennine Fault. On the south of the Lake District there are detached patches in Cartmel and Low Furness, and on the west a strip extending from the Duddon estuary to St. Bees Head, but they attain their greatest development between Penrith and Carlisle, and in the valley of the Eden. The lowest bed of the series is the Penrith Sandstone, consisting of a rather coarse-grained dark-red sandstone of fairly uniform character, which, with its underlying and overlying breccias (locally called brockram), attains a thickness of 1,500 feet. The rock shows a great amount of false bedding, but contains no trace of animal remains, except some footprints of chelonians. Above the upper brockram, there is a series of alternating beds of pale yellow sandstones, with thin films of clay between, of reddish dolomitic sandstones, marl slate, bands of impure dolomite and shale, about 150 feet in thickness. Some of the light yellow sandstones, clays, and shales are crowded with carbonised plant remains, mostly in too fragmentary condition to be identified. These beds may be seen in Hilton Beck, about a mile below the village of Hilton. Overlying the plant beds there is a thin band of magnesian limestone, in some places reaching ten feet in thickness. It, too, yields fossils in considerable numbers, including Polyzoa, Brachiopods, Lamellibranchs, and Gasteropods; also, Ganoids, Amphibians, and some traces of Reptilian remains.

The plant beds and magnesian limestone form the dividing line between the Upper and Lower New Red Rocks.

The magnesian limestone is overlaid by about 300 feet of gypseous marls, red shales, and micaceous flags, having at the base, in some places, a band of conglomerate. Above the gypseous marls there is a great thickness, probably over 1000 feet, of Venetian-red sandstones, with occasional white bands, and bands of mottled sandstone, interstratified with beds of red sandy shale and marl, which are known as the St. Bees and Kirklinton Sandstones. Excellent sections of the St. Bees Sandstone may be seen at Raven Beck, a tributary of the Eden, at Shalk Beck, south of Curthwaite Station, on the Maryport and Carlisle Railway, and at St. Bees Head; and the overlying Kirklinton Sandstone may be seen in the parish of Kirklinton, at Rockliffe, and at Netherby.

Above the Kirklinton Sandstone there is, around Carlisle, well on to 1,000 feet of Keuper Marls, with rock salt, gypsum, and, near the base, flags and thin beds of magnesian limestone. There is also a small outlier of lias, about four miles west of Carlisle.

The New Red Rocks on the margin of the Lake Country have been very ably mapped and described by the officers of the Geological Survey, Messrs. J. G. Goodchild, F.G.S., T. V. Holmes, F.G.S., in the *Quarterly Journal*, vol. 37; *Proceedings of the Geologists' Association*, vol. 7; and *Transactions of the Cumberland and Westmorland Association*, No. 17, 1891—92.

The Hilton Shales, or Plant of Beds, have yielded the following species :—

Alethopteris Goepperti. Naum
Cardiocarpum triangulare. Gein.
    the seed of species of Ullmania.
Odontopteris sp.
Sphenopteris dichotoma. Althaus.

Sphenopteris Naumanni. Gutbier.
„ sp.
Ullmania selaginoides, } Cones, leaves, bracts, and branches.
„ bronnii

SURFACE DEPOSITS, OLD LAKES, MORAINES, AND BOULDERS.

Many of the valleys beneath the highest mountain masses, contain numerous irregular mounds of moraine material, some of which have been cut through by streams. Excellent examples may be seen in the St. John's, Greenup, Longstrath, Ennerdale, Buttermere, Lorton, Grisdale, Hartsop, and many other valleys. The rocks on the mountains, and on the sides of the valleys, are in many places rounded and grooved by glacial action. In the valleys, there are also numerous patches of boulder clay, containing occasionally striated and grooved boulders. On many of the Skiddaw Slate mountains, notably Latrigg, eastern end of Skiddaw, Blencathra, Newlands Hawse, Melbrake, &c., there are perched blocks of ash and trap from the volcanic series, at all elevations up to 1,500 feet, and the river courses in the Skiddaw Slate valleys are filled with boulders that have been transported from the mountains of the volcanic series. There are, I believe, few localities in the Lake District where the effects of glacial action may be seen to greater advantage than in the valleys of the Greta and its tributaries; and certain works that were in progress on the Cockermouth, Keswick, and Penrith Railway, in 1894 and the two following years, consisting of the extension of sidings and enlargement of the stations at Keswick and Threlkeld, and the doubling of the line between Threlkeld and Troutbeck stations, a distance of 4¾ miles, afforded exceptional opportunities for the examination of the surface deposits left by glaciers in the localities named. The excavations in connection with these works were made chiefly in glacial drift and boulder clay, and these materials, which cover most of the moorland between Troutbeck and Threlkeld Stations, consist of a stratum of brownish clay containing a large number of boulders, and also large quantities of smaller stones and pebbles, many of them being grooved and scratched; it varies in thickness from three feet to six feet, the greatest thickness occurring near Threlkeld Station, and towards the bottom of the valley. The brown clay is overlaid in some places by a thin covering of peat, and in others by a thin stratum of poor clayey soil. Beneath the brown clay is a bed of blue clay, containing boulders and pebbles almost as numerous as those in the brown clay above. The blue clay appears to vary in thickness from about six feet to nine feet, and shows the same tendency to thicken towards the bottom of the valley; but in many of the cuttings the bottom of the blue clay was not reached, and its actual depth could not be ascertained. The dip of the beds coincides in a general way with the present configuration of the surface.

The blue clay is manufactured into tiles and drain pipes at Troutbeck Station, and was formerly used for brick-making near Threlkeld Station.

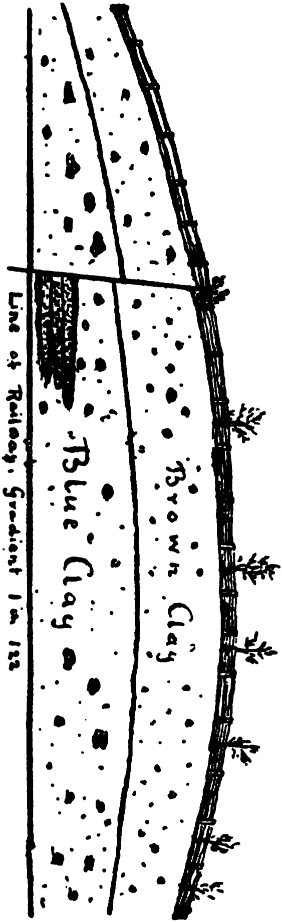
The whole of this material has doubtless been brought down by glaciers, or rather by a continuous ice-sheet flowing northward from Clough Head and Wolf Crag, at the northern end of the Helvellyn range, nearly all the boulders and pebbles in the drift being fragments from the volcanic rocks of the Borrowdale Series.

About a quarter of a mile north-west of Threlkeld Station the rivers Beur and Glenderamakin unite and form the Greta, which runs through a deep narrow valley, 2½ miles, to Keswick. The valley of the Greta is extremely narrow at its eastern and western extremities, and the banks of the river are very high and precipitous, except in the middle portion, where it crosses the mouths of the Glenderaterra valley on the north and the Naddle valley on the south.

During the greatest intensity of the glacial epoch, the pressure of the ice must have been very great in the valley of the Greta; in addition to the sheets flowing from the northern end of Helvellyn, and from the summit of Blencathra on the opposite side of the valley, glaciers also flowed down the vales of St. John and Naddle. The greater portion of this vast mass of ice must have forced its way through the valley of the Greta, and thence seaward through the valley of the Derwent, a small quantity only finding an outlet northward into Skiddaw Forest, through the narrow Glenderaterra valley, and carrying with it a few boulders from the volcanic series. The eastern end of the Threlkeld valley would at that time be blocked by a glacier flowing down the valley of the Glenderamakin. The valley of the Greta was then filled with ice above the level of the top of Latrigg (1,200 feet): abundant evidence of this is afforded by the large number of perched blocks and boulders from the volcanic series left on the top of Latrigg and on the southern slope of Lonscale Fell. Later, when the ice melted, vast numbers of boulders of all sizes were left scattered along the southern side of the valley, mostly from the ashes and lavas of the Borrowdale Series, and associated igneous rocks. Most of the ground on the northern side of the valley is too precipitous to permit of boulders finding a lodging place there; indeed, if boulders were stranded anywhere on that side, except at or near the mouth of the Glenderaterra valley, they must long ago have toppled into the Greta, the bed of which is thickly strewn with them. There are no traces of ice scratches on the rocks in the valley of the Greta, owing partly to the rapid erosion of the bed of the river, and partly to the soft nature of the Skiddaw Slate on which scratches may have been left; but at the mouth of the valley, where it opens into the broad vale of the Derwent, thick and extensive masses of boulder clay and glacial drift have been deposited. The tunnel (100 yards in length) on the railway, half a mile east of Keswick Station, and on the southern side of the river, was excavated almost entirely in blue clay, measuring sixteen feet in thickness, overlaid by one foot of sand and twelve feet of brown clay. The clay at the eastern end of the tunnel has often given great trouble to the engineering department in wet seasons. The line at that point is protected by a retaining wall of massive stone work, 37 feet in height, above which there is a steeply sloping bank, consisting of 40 feet of blue and 10 feet of brown clay. Several landslips have occurred in this bank, although numerous rows of piles have been driven into it. A portion of the massive retaining wall was on one occasion overturned, and the line was blocked by the debris and a moving mass of clay.

On the same side of the river, and three-quarters of a mile to the west, stands Southey Hill, which is capped by glacial drift. the brown clay being present but not the blue clay. On the northern side of the river there is a long strip of drift material, extending from the Keswick Hotel and the eastern side of the railway station to the western side of Crosthwaite Church, a distance of about a mile, The sequence here is the same as between Threlkeld and Troutbeck Stations, but the beds are thicker. In the cutting, on the northern side of the hamlet of Great Crosthwaite, they were proved to a depth of 23 feet; and in the section which was a short time ago exposed, in extending the siding at the western end of Keswick Station, they measure as follows:—Brown Clay, 10 feet; Blue Clay, 15 feet (but the base of the blue clay was not exposed and its entire thickness was not ascertained). Both the brown and the blue clays contain the same proportion of boulders and pebbles as in the localities previously mentioned, many of them being a good deal scratched; but they differ from those found in the cuttings east of Trelkeld Station, in having amongst them a considerable number of fragments of Skiddaw Slate, and the author found there two pebbles of quartz felsite from the Armboth

Dyke. The section at Keswick Station is 130 yards in length, but there is a slight break in it, 50 yards of the western end being cut back nine feet to the north. At the point where the break occurs, and for 17 yards eastward, some beds of current-borne materials take the place of the lower part of the blue clay. There is a bed of very fine sediment, of a brown colour, one foot thick, above it there is two feet of fine sand, and above that a bed of coarse gravel and pebbles, which is succeeded by blue clay of the usual type. The whole of these beds dip to the south-west at an angle of about nine degrees. Directly south-west, and at right angles to this section, across the Fitz Park and the River Greta, is Southey Hill, distant about one-third of a mile, and the



Cutting at Western end of Keswick Railway Station drift beds just described have at one time probably been more or less continuous across the intervening space, and, if so, the whole of it has since been scooped out by the river to a depth of 30 feet, and in the present bed of the river, 40 feet below the floor of the valley as it probably stood when the deposition of glacial drift commenced.

The amount of post glacial denudation observed here is much greater than in some other localities, but the evidence in support of it is, I think, sufficiently conclusive. The presence of the beds of water-borne sediment, sand, and gravel, at or close to the base of the section at the western end of Keswick station yard, occurring as they do at the foot of Latrigg and at the western corner of that projecting spur of Skiddaw, far from any stream which could possess sufficient force to cause the formation of such beds, one is almost forced to the conclusion that they could only have been deposited by the Greta when it was flowing at that level. A considerable amount of denudation has also occurred at the eastern end of Forge tunnel, but as the river has had to cut its way chiefly through rock, its erosive action has not been so effective there as on the softer material a little further to the west. The tunnel, and the deep cutting at the western end of it, are no doubt in an ancient bed of the river, which has been blocked by a landslip of tough boulder clay, and the river has since been compelled to cut its way into the more yielding material on its northern bank; the present bed of the river is 26 feet below the ancient bed which was blocked by boulder clay.

Numbers of peat-mosses and bogs, on the mountains and in some of the valleys, mark the sites of old tarns and lakes. A large oval area of peat, between Blea and Watendlath Tarns,

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The author has spent a considerable amount of time in searching for shells, or fragments of shells, in both the blue clay and the brown clay, but hitherto without success; further diligent search may, however, yet be rewarded.

represents a tarn as large as the former. Shoulthwaite Moss was clearly a lake, at a period not very remote; and there was probably another, somewhat larger, in the Naddle Valley.

Numerous masses of drift material occur in the valleys, consisting of sub-angular gravel and beds of sand, stratified and false bedded. An excellent example of this kind of deposit may be seen at Bassenthwaite Lake Station, also between Bassenthwaite Lake and Embleton. A similar, but smaller, deposit may be seen just south of the railway, above Brigham, Keswick.

FAULTS AND MINERAL VEINS.

The faults and veins of the Lake District belong to two systems, one having a prevailing E.N.E. and W.S.W., and the other a N.N.W. and S.S.E. direction. The former coincide with the strike of the older rocks, and are much older than the latter, as they do not affect any strata of later date than the Upper Ludlow formation. No date can be assigned to the newer, or N.N.W. and S S.E. system. The best-known example of this system is the Pennine fault, which dislocates the strata to the extent of not less than from 6,000 to 7,000 feet, and forms that important geographical feature known as the Pennine Chain. In the Lake District proper, the most important of the newer system is one that extends from Skiddaw Forest, through the Glenderaterra and Thirlmere valleys, thence through Dunmail Pass, along the depression occupied by Grasmere, Rydal, and Windermere Lakes. Its presence can be detected near Ambleside by the shifting of the Coniston Limestone to the south. Another parallel fault probably extends through the depression occupied by Bassenthwaite and Derwentwater Lakes, through Borrowdale and the valley in which Coniston Lake lies. This has also shifted the Coniston Limestone at Coniston Waterhead. A third probably passes along the valley of Lorton, through Crummock and Buttermere Lakes, terminating in the Duddon estuary. It is also probable that there are faults in the Shoulthwaite and Watendlath valleys, and many more of minor importance that have since become mineral veins. Others no doubt exist, but owing to the absence of clearly marked and persistent beds in either the Skiddaw Slates or Volcanic Series, their presence can only be conjectured by the general want of harmony between the beds on opposite sides of some of the valleys. The most important of the older system is no doubt the great boundary fault between the Skiddaw Slates and the Volcanic Series, which extends in a zigzag course from near Egremont to the eastern end of Mell Fell. A parallel fault probably extends from the coast of West Cumberland, up the valley of Eskdale, and is prolonged through the Grisedale Valley and the depression of Ullswater Lake. Some geologists have expressed an opinion that there are faults which correspond with each of the valleys in the district, and that the valleys have been scooped out by the various denuding agents acting along the lines of fracture with greater effect than elsewhere, but the evidence in support of this theory is by no means conclusive, whilst there are numbers of mineral veins cutting through mountains and valleys in all directions without altering the configuration of the surface in the smallest degree.

Mineral veins are very numerous in the Skiddaw Slate rocks, many of them are large and are filled with a variety of metallic and non-metallic minerals; but the deposits of metallic minerals or metalliferous ores are irregular, occurring in detached sops more frequently than in continuous pipes. The vein-stone is sometimes softer than the enclosing rock, frequently consisting of friable quartz, although there are occasionally large quantities of hard and compact quartz. In some instances, however, the ore is associated with disintegrated slate of a clayey nature, which miners call "douk."

Veins are not so numerous in the Volcanic Series as they are in the Skiddaw Slates, but some of them have been more productive, and the deposits of ore are more persistent and extensive. The vein-stone, like the enclosing rocks, is usually very hard, and the ore is a good deal intermixed with it, being less frequently found in solid masses, like the larger deposits in the Skiddaw Slates. At the Roughtengill Mine, in the volcanic rocks of the Caldbeck mountains, there were almost continuous deposits extending over 600 fathoms in length and 100 fathoms in depth. At Coniston and Greenside mines, both of which are in the Volcanic Series, there were richer deposits, extending over 200 fathoms in length and 200 fathoms in depth. But the most valuable and extensive deposits of metalliferous ore occur in connection with the veins in the carboniferous limestone—of hematite iron in West Cumberland, and of galena in the Cross Fell range. In both of these localities, but especially in the former, the ore occurs not so much in the veins as in flats and in deposits of irregular shape connected with the veins.

In early geologic ages, the rocks of the Lake country have been subjected to much crumpling and folding, and there have been repeated elevations and depressions of its surface, some of which may have been sudden and others gradual. It has also suffered very extensive denudation from the eroding action of the weather during countless ages of exposure to its forces; also from the action of rivers, glaciers, and the waves and currents of the ocean, beating upon the land, while slowly rising to or sinking beneath its surface. There has also probably been a certain amount of crushing and partial crumpling of the strata, by lateral pressure, in later geologic ages, caused by the shrinking of the earth's crust; and thus portions of the arena acted upon would be elevated and others depressed in a corresponding degree. When an elevation of this kind occurred at the mouth of a valley, or a depression at its head, a lake basin would be formed or an existing one deepened. In some rare cases, the reverse movement may have emptied pre-existing lakes, but it is more than probable that some of the lakes, and also of the tarns, owe their origin to the damming of the rivers and valleys by undulations produced in the rocks by lateral pressure. In December, 1894, a Paper entitled, "The Tarns of Lakeland," was read before the Geological Society, by Mr. J. E. Marr, F.G.S. (*Quarterly Journal*, vol. 51), in which it was shown that many of the tarns in the Lake country owe their existence to the damming of small valleys by moraine material and glacial drift; also that in some tarns, the original outlet had been dammed by a mass of glacial drift, and the surface of the water thereby raised until it found a fresh outlet in another direction.

SUMMARY.

The rocks of the Lake country have been formed under very different conditions. The Skiddaw Slates, as we have before seen, were deposited at or near the mouth of a large river, and that the sea then teemed with low forms of animal life, while the Volcanic Series was laid down under fiery and death-dealing conditions that must have been destructive of every form of life. Then a depression took place, and the Coniston Limestone, with its shales, was deposited, in a moderately deep sea. Afterwards, there was a partial re-elevation, and return of deltaic conditions before the deposition of the overlaying shales, grits, and slates. The upward movement continued, and the embryo Lake District was an island during the deposition in other quarters of the Llandovery group. Another slight depression prepared for the deposition of the Ludlow rocks, after which it was again elevated, and remained exposed to denudation during a very long period, represented elsewhere by the deposition of the Old Red Sandstone. J. C. Ward, F.G.S., estimated that during this period of denudation 20,000 feet of rock was removed from the surface of the Lake country.* The land again began to sink, and the basement conglomerate was formed of fragments torn from the sinking surface. The downward movement continued very slowly through the whole time occupied by the deposition of the carboniferous series, during which a semi-tropical climate prevailed. Afterwards, the land was again elevated, and the Permian and Triassic rocks were formed, probably in a large inland lake, on the muddy shores of which nondescript chelonians wandered in search of food, leaving their curious foot-prints associated with the marks of rippling waves. From the commencement of the Permian Age to the close of the glacial epoch, the Lake District was undergoing sub-aërial denudation, and the mountains and valleys had assumed very much the form they now possess.

During the greatest intensity of the glacial epoch, the Lake country was smothered beneath a mass of moving ice, which deepened its valleys, ground off the angles of the rocks, rounding and grooving them, using for graving tools the fragments already torn off. Towards the close of this epoch, each valley was occupied by a glacier, which gradually diminished year by year, until they finally disappeared. At the end of the glacial period, the land once more sank beneath the sea, and emerged again without any interval of rest, the gravels and other surface deposits being re-arranged during the operation.

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*At the commencement of this period of denudation, it is probable that the Ludlow rocks and underlying lower Silurian strata, had a considerable extension northwards, over the Ordovician Series.

It is a very difficult matter to form a true conception of the vast periods of time required for the formation of all the strata represented in the Lake District, but an illustration used by the late J. Clifton Ward, F.G.S., may be of some service. He said, if the distance between Keswick and the twelfth milestone on the road to Ambleside be taken as the distance in geologic time from the present to the remote age when the sediment of which the Skiddaw Slate rocks are formed began to accumulate, then 80 feet along that road would represent the time from the present to the close of the glacial epoch. In other words, as 80 feet is to 63,360 feet, so is the lapse of time backward from the present, to the close of the glacial epoch, compared with that reaching back to the commencement of the Skiddaw Slate period.

Mr. Croll estimated that 80,000 years have elapsed since the close of the glacial epoch, but Major-General A. W. Drayson, F.R.A.S., states that the "glacial epoch terminated not longer than 6,000 years ago, and lasted not longer than 18,000 years." (*Transactions of the Victoria Institute*, vol. 26, p. 260). The latter statement is much more in harmony with the evidence afforded by the comparatively recent marks of glaciation left on our Lake Country rocks, and by the deposits of glacial drift and boulder clay.

THE MINERALS OF THE LAKE DISTRICT.

The veins of the Lake District contain many rare and beautiful minerals; more, probably, than are to be found in any area of equal size in the United Kingdom, or even in Europe. One mine alone, namely, Roughtengill, near Caldbeck, yields no less than twenty-three distinct species or varieties. About 108 varieties in all, either occur in the veins, or are disseminated through the rocks of the Lake District:

52 of which are non-metallic, and 56 metallic. It is not my intention to treat of each species in detail, but merely to give a short description of the principal non-metallic rock-forming minerals, and those of the metallic order that are of the greatest importance in a commercial point of view.

NON-METALLIC MINERALS.

Graphite, or Plumbago, commonly called black lead, is composed of about 96 per cent. of carbon, and 4 per cent. of iron; and the specific gravity of the best quality is about double that of water. It is used chiefly in the manufacture of pencils, cleaning and glossing cast iron work, such as stoves, grates, &c.; but also forms an ingredient in several anti-attrition compositions, and being capable of enduring great heat without fusing or cracking, it is, owing to this property, used in the manufacture of crucibles. Graphite is found at Seathwaite, in Borrowdale, in its best and purest form; and being the only species that can be manufactured into fine-pointed pencils, in its natural state, it is of great value.

Coal is composed of carbon, with oxygen, hydrogen, nitrogen, and earthy matter in varying proportions; the quantity of bituminous matter amounting to from ten to sixty per cent. in different kinds. Its appearance, and the purposes for which it is commonly used, are well known to all; but owing to the progress made in chemical science, saccharine, ammonia, and a variety of beautiful aniline dyes are now obtained from substances which formerly were waste residuals of coal that had been used in the manufacture of gas.

Fluor Spar occurs very plentifully in the District, chiefly in the carboniferous rocks. Like galena, with which it is often associated, fluor generally assumes the form of cubes, and these intersect each other in every direction, without losing their individuality. It occurs in a great variety of colours, the most common of which are green, blue, and lilac, each again varying in light and darker tints. The most beautiful specimens of this mineral that the District has produced have been obtained in the mines about Alston.

CALCITE, or carbonate of lime, is more abundant than fluor, especially in veins in the carboniferous rocks. It probably assumes a greater variety of crystalline forms in this District than in any other part of the world; sometimes it is found in clear glassy crystals, but generally more or less coloured, ranging through various shades of grey, brown, salmon, cream, or rose colour. It is often found, in the form of stalactites and stalagmites, in fissures in the limestone.

ARAGONITE is a variety of carbonate of lime, found in considerable quantities in the iron mines in West Cumberland, and in the neighbourhood of Alston. It sometimes occurs in branching shrub-like forms, resembling coral, but more commonly in long, almost transparent, spike-like crystals. There is also a fibrous variety, called satin spar.

DOLOMITE is one of the prettiest minerals we have. It often occurs as a crystalline incrustation on hematite at Cleator, and on blende and galena in the mines near Keswick. The mineral is a carbonate of lime and magnesia, generally cream-coloured, and of a pearly lustre; but sometimes the colour is saffron-yellow, or a dark rich brown.

BARYTES consists of sulphate of baryta, associated very often with a small admixture of other minerals, namely, sulphate of strontia, peroxide of iron, sulphate of lime, and silica. It is a very heavy mineral, generally more or less crystallised; in some cases colourless and transparent, in others white, but more commonly grey or yellow. Barytes is used largely in the manufacture of plate glass, in the adulteration of white lead, the preparation of mixed paints, as a flux in copper smelting, and in small quantities for various other purposes. The localities where it is found are Greenside, Blencathra, Roughtengill, Ruthwaite, and very plentifully at Force Crag mine.

GYPSUM (sulphate of lime) is found occasionally as clear crystals, in veins near Alston, and at St. Bees, but it occurs in large quantities in shales, associated with the magnesian limestone, and is worked for commercial purposes at Little Salkeld, near Penrith, and other places in Cumberland and Westmorland.

APATITE (phosphate of lime) occurs in some of the veins at Brandy Gill, in prismatic crystals, many of which are small, but they sometimes attain a large size. It also occurs in small quantities in some of the granites and volcanic rocks. The colour is generally a pale yellowish green.

QUARTZ (silica) is one of the most important rock constituents in the Lake District. It is present everywhere, more or less, in the older rocks, from the crystalline granite to the soft sedimentary slate. All the metalliferous veins in the older rocks are quartz veins, but in the veins in the carboniferous and newer rocks it is comparatively rare. The crystals are generally in the form of a six-sided prism, terminated by a six-sided pyramid, sometimes clear and colourless, but often tinted by oxides of iron, manganese, and other minerals. Frequently, however, both in veins and small strings, it is of an opaque milky-white colour. When examined microscopically it is seen to be full of minute cavities, nearly filled with water, and the tiny vacuity in each cavity, like the bubble in a spirit level, is always in a state of restless motion. These cavities are of all shapes, some round, others almond-shaped, or long and branching, but they are so numerous that if a piece of perfectly dry vein quartz is broken, the fractured surface is instantly covered with moisture. The size of the cavities vary from 1-2000th to 1-10000th of an inch in diameter. By careful experiments, Mr. Sorby and other workers have shown that quartz was formed under great pressure, and at a heat that would be visible in the dark as a dull red. The water, thus heated, would be unable to turn into vapour owing to the great pressure, and, having been enclosed in that condition, would contract slightly on cooling, and by that means cause the tiny vacuity to be formed. Basing a calculation on the relative size of the liquid cavities, and the vacuities in them, J. Clifton Ward, F.G.S., estimated that the quartz in the Skiddaw Granite was formed under a pressure of more than an equivalent of 50,000 feet of rock ; and that the mean pressure under which all the principal granitic and granitoid rocks were consolidated was equivalent to 44,000 feet of rock.

EPIDOTE is a yellowish-green mineral, occurring in most of the volcanic rocks ; it is very abundant in some of the beds of the Falcon Crag series, where it fills up small fissures and cavities with its slender needle-like crystals.

FELSPAR is an important constituent of nearly all the plutonic rocks in the District. It occurs in a variety of forms, and is often much altered. The following varieties have been found in Cumberland and Westmorland :—orthoclase, oligoclase, plagioclase, labradorite, andesine, albite, microline, and probably sanidine.

CHLORITE is probably the most prominent mineral in the rocks of the volcanic series. When seen in a massive state it is of a dark olive-green colour, and it is owing to its presence, so widely diffused through the rocks, that their prevailing green tint is due. It is probably a decomposition product of several other minerals.

METALLIC MINERALS.

Gold. A small portion of gold has been found at Goldscope mine, associated with chalcopyrite; and at Brandlehow mine, in quartz and red gossan. Respecting the former, we are informed in Gibson's *Camden's Britannia*, that the ore raised at this mine was so rich in gold and silver, that the value of these two minerals extracted from it was greater than that of the copper with which they were associated.

Silver is contained in nearly all lead and copper ores; some of the former yield as much as 144 ounces per ton;* but the average yield is about 16 ounces. The lead ore raised at Silvergill and Driggith mines, near Caldbeck, contained about 25 ounces; and the Force Crag ore about 35 ounces per ton. The weight of silver extracted from lead ore raised in the counties of Cumberland and Westmorland, in 1888, was 16cwt. 0qrs. 23lbs. avoirdupois, representing in value £7,260.

Iron, although of less commercial value than gold and silver, is really the most important of all minerals. It occurs in irregular-shaped deposits, some of which are of immense size, in the carboniferous limestone in the Cleator and Furness districts; and in veins, in the Skiddaw Slate, at Kelton, Knockmurton, &c.; also in small quantities in the volcanic series, and in the granitic and other igneous rocks in various localities. It consists chiefly of hematite; but small quantities of the more rare species are also found, such as mispickel, limonite, siderite, ilmenite, and pharmacosiderite. Hematite is composed of about 70 per cent. of iron and 30 per cent. of oxygen. In colour it varies from dark-red to purple, and is generally very hard and compact, having a metallic lustre and an uneven fracture. Sometimes small cavities occur in it, adjacent to which the ore assumes the form termed "kidney ore," so often seen in mineralogical cabinets, and which exhibits the mineral in a high state of purity. In these cavities rock crystal frequently occurs; also calcite, aragonite, dolomite, &c.

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* Found in County Clare, Ireland.

IRON PYRITES, or iron bisulphide, is composed of about 46 per cent. of iron and 54 per cent. of sulphur. It is a hard mineral, emitting sparks when struck with steel; is of the same colour as brass, and burns with a blue flame when subjected to the action of fire. It occurs, more or less, in all the rocks and veins of the Lake District, both massive and crystallised; whatever the dominant ore in a vein may be, iron pyrites will also be present to some extent. It almost invariably assumes the cubical form, and the crystals are sometimes of a large size. Very beautiful specimens are obtained from the mines near Keswick, in some of which the pyrites occurs as an incrustation on galena, and in others the crystals appear in all the tints of purple, pink, and green. Isolated cubes of iron pyrites also occur in considerable quantities in some parts of the Skiddaw Slate rocks, and occasionally in the volcanic series; these cubes frequently decompose, leaving a square cavity in the slate. Specimens of Skiddaw Slate are sometimes found on which the decomposing iron pyrites has deposited a film, which displays all the colours of the rainbow. Iron pyrites occurs in considerable quantities at Woodend mine, near Threlkeld, and Caldbeck Fells; but it has not been mined profitably except at Alston and near Millom. About 500 tons were raised in Cumberland in 1880, worth about £250.

PSILOMELANE, or hydrous peroxide of manganese, is a brittle mineral, of a black or bluish-black colour, and consists of about 70 per cent. of manganese, 8 per cent. oxygen, 16 per cent. baryta, and 6 per cent. water. It is used in the manufacture of glass, and in bleaching. The localities where it is found are Caldbeck Fells, Blencathra, and Force Crag.

Cobalt. Two varieties of this mineral, namely, erythrine, and smaltine, are found in the cobalt mine, in the Causey Pike range, between Sail and Scar Crags. Erythrine, or arseniate of cobalt, is of a dull peach-red colour, inclining to blue, and yields about 38 per cent. of arsenic acid, 37 oxide of cobalt, 1 protoxide of iron, and 24 of water. Smaltine, or cobalt pyrites, consists of about 20 per cent. of cobalt, 4 of iron, 75 of arsenic, and 1 of sulphur, It has a metallic lustre, and varies in colour from tin-white to steel-grey. The mineral is used chiefly in the fine arts, and is about equal to silver in value.

Copper is found in the Lake District in a variety of forms and colours, numbering no less than eight distinct varieties, namely—pitchy copper, malachite, olivenite, melaconite, brochantite, chrysocolla, chalcosine, and chalcopyrite or copper pyrites. The last named is the most plentiful, in fact the greater part of the copper produced in the United Kingdom is obtained from copper pyrites. It is composed of about 31 per cent. of copper, 33 of iron, and 36 of sulphur, and is generally of a brass-yellow colour; but the surface is frequently, variegated with red, purple, pink, and green. The localities where it occurs most plentifully are Coniston, Goldscope, Dale Head, and Caldbeck Fells.

Antimonite, or sulphuret of antimony, is a mineral of a lead-grey colour, frequently blackish, and having a metallic lustre. It is composed of about 74 per cent. of antimony, and 26 of sulphur. The localities where it has been found are Robin Hood mine, Bassenthwaite, Wanthwaite mine, and Carrock Fell. When the railway between Keswick and Penrith was being constructed, a solid lump of sulphide of antimony, weighing 1 cwt., was found in the drift clay, at Troutbeck Station; it had no vein-stone or rock attached that would indicate the locality whence it was derived.

LEAD. Ten distinct varieties of this mineral are found in the Lake District, some of which assume very beautiful forms and colours; the most common are cerussite or carbonate of lead, and galena or sulphide of lead. The former is composed of about 83 per cent. of oxide of lead, and 17 of carbonic acid. In colour it is white or grey, and sometimes reddish-brown. The crystals are usually long, slender, and pointed, sometimes as fine as needles, and almost as long; specimens consisting of an open network of crystals of this kind were sometimes obtained from the Brandlehow vein, large as an orange and white as snow, but the tenderest care failed to preserve them from gradually falling to pieces. Cerussite is also found at Yewthwaite, Barrow, Force Crag, and at Caldbeck Fells. Galena, which is the most prevalent form of lead ore, contains about 86 per cent. of lead and 14 of sulphur, and its colour is a greyish-blue. The crystals, which are cubic in form, are sometimes large and occasionally very small; the latter, commonly termed fine-grained ore, contains a larger proportion of silver. Galena occurs in all the lead mines in the District, associated with cerussite, blende, calamine, chalcopyrite, malachite, and iron pyrites. The more rare species of lead, namely, anglesite, linarite, leadhillite, caledonite, pyromorphite, mimetisite, and stolzite, are found at Caldbeck Fells, except the last named, which occurs at Force Crag mine.

ZINC. Four varieties of zinc ore are found in the Lake District, namely, blende, calamine, aurichalcite, and Smithsonite, but the last three occur in small quantities. Blende, or sulphide of zinc, is a mineral of a dark reddish-brown colour, sometimes almost black. It occurs usually with galena, chalcopyrite, and iron pyrites; and, like galena, it crystallises in the cubic form. Beautiful specimens of this mineral are obtained in the mines near Keswick, some of them having the cubes encrusted with quartz or dolomite; and they are much sought after owing to the beautiful lustre of the mineral and its non-liability to tarnish when exposed to the air. Blende is nearly as heavy as lead ore, and of the same weight as iron pyrites, hence it is a very difficult matter to separate it from these minerals, and it is almost invariably associated with them. The localities where it is found most plentifully are Force Crag, Woodend, and Thornthwaite mines.

None of the metallic minerals, except iron pyrites, are ever found apart from mineral veins, or the small strings connected with them. The flats in which lead ore is found in the carboniferous limestone, near Alston, and the irregular deposits of hematite, in the same formation in the Cleator and Furness districts, are also connected with veins; and it is by the aid of those veins that the miner is guided in his search for metallic ores.

LIST OF THE MINERALS FOUND IN THE LAKE DISTRICT.

NON-METALLIC MINERALS.

NAME.	DESCRIPTION.	LOCALITIES.
Actinolite	Variety of hornblende	Igneous rocks
Agate	Variety of quartz	Castlerigg Fell
Albite	Variety of felspar	Igneous rocks
Alstonite	Double carbonate of lime and barytes	Alston
Andesine	Variety of felspar	Igneous rocks
Anhydrite	Sulphate of lime	Coat Hill
Apatite	Phosphate of lime	Igneous rocks
Aragonite	Carbonate of lime	Alston, Cleator, &c.
Augite	Bi-silicate of lime and magnesia	Igneous rocks
Barytes	Sulphate of baryta	Force Crag mine, &c.
Beryl	Alumino-glaucinum silicate	Walla Crag
Biotite	Variety of mica	Igneous rocks
Chalcedony	Variety of quartz	Roughtengill
Calcite	Carbonate of lime	Greenside mine, &c.
Carnelian	Variety of quartz	Castlerigg Fell
Chert	Crypto-crystalline silica	Edenside
Chiastolite	Variety of andalusite	Glenderaterra Valley, &c.
Chlorite.	Hydrous silicate of magnesia and iron	Falcon Crag, &c.
Coal	Mineralised vegetable matter	West Cumberland collieries, &c.
Corundum	Variety of sapphire	Carrock
Diallage	Bi-silicate of magnesia and oxide of iron	Carrock
Dolomite	Bi-carbonate of lime and magnesia	Sparry incrustation on blende from Brandlehow and Woodend mines, &c.
Enstatite	Bi-silicate of magnesia	Igneous rocks
Epidote	Bi-silicate of alumina and lime	Walla Crag, &c.
Flos-Ferri	Variety of aragonite	Dufton
Fluor, Fluorite	Fluoride of calcium	Alston, &c.
Garnet	Bi-silicate of alumina and lime	Great Gable, &c.
Gilbertite	Variety of mica	Skiddaw Granite
Graphite	Carbon	Seathwaite, Borrowdale
Gypsum	Sulphate of lime	Little Salkeld, &c.
Hornblende	Bi-silicate of magnesia and lime	Igneous rocks
Idocrase	Variety of felspar	Wastdale Crag, Shap
Jasper	Variety of quartz	Castlerigg Fell
Labradorite	Variety of felspar	Igneous rocks
Mica	Silicate of alumina, iron and potash	Glenderaterra Valley
Microline	Variety of felspar	Igneous rocks
Muscovite	Variety of mica	Glenderaterra Valley

NON-METALLIC MINERALS—*continued.*

NAME	DESCRIPTION.	LOCALITIES.
Olivine	Bi-magnesian silicate	Igneous rocks
Oligoclase	Variety of felspar	Do.
Orthoclase	Variety of felspar	Do.
Pectolite	Silicate of lime and alumina	Veins on north side of Pennine Fault
Quartz	Silica	All veins and rocks in the Ordovician Series
Sanidine	Variety of felspar	Igneous rocks
Satin spar	Variety of aragonite	Dufton
Schorl	Variety of tourmaline	Threlkeld quarry
Serpentine	Hydrated monosilicate of magnesia, &c.	Igneous rocks
Selenite	Hydrous calcium sulphate gypsum	Coat Hill
Strontianite	Strontium carbonate	Alston
Sulphur	Sulphur	Dufton
Sodium chloride	Common salt	Eden Valley and Brandlehow mine
Talc	Hydrous magnesian monosilicate	Igneous rocks
Tourmaline	Boro-silicate	Carrock
Witherite	Barium carbonate	Dufton

METALLIC MINERALS.

NAME.	DESCRIPTION.	LOCALITIES.
Antimonite	Sulphide of antimony	Robin Hood mine, Bassenthwaite, &c.
Anglesite	Sulphate of lead	Caldbeck Fells
Aurichalcite	Hydrous carbonate of zinc	Roughtengill
Bismuth (native)	Bismuth	Brandy Gill
Bismuthine	Sulphide of bismuth	Do.
Blende	Sulphide of zinc	Woodend & Thornthwaite mines, &c.
Brewsterite	Protoxide of copper	Roughtengill
Brochantite	Sulphate of copper	Do.
Calamine	Carbonate of zinc	Do.
Caledonite	Cupreous sulphate, carbonate of lead	Red Gill
Cerussite	Carbonate of lead	Yewthwaite, &c.
Chalcopyrite	Sulphide of copper	Goldscope, Coniston, &c.
Chessylite	Carbonate of copper	Harcla
Chrysocolla	Hydrous copper, monosilicate	Caldbeck Fells
Erythrine	Hydrous arseniate of cobalt	Cobalt mine, near Scar Crag
Fahlerz	Sulph-antimonide of copper	Clouds, near Kirkby Stephen
Galena	Sulphide of lead	All lead mines
Gœthite	Monohydrated ferric oxide	West Cumberland iron mines

METALLIC MINERALS—*continued.*

NAME.	DESCRIPTION.	LOCALITIES.
Gold	Gold	Goldscope and Brandlehow mines
Hausmannite	Manganese protoxide	West Cumberland iron mines
Hematite	Ferric oxide	West Cnmberland iron mines
Hydrozincite	Zinc bloom	Alston
Ilmenite	Titanic iron	Carrock
Iron pyrites	Sulphide of iron	Woodend mine, &c.
Johnstonite	Sulphuret of lead	Dufton
Leadhillite	Sulphate tri-carbonate of lead	Red Gill
Limonite	Brown hematite iron	Woodend mine, &c.
Linarite	Sulphato-carbonate of lead	Roughtengill, &c.
Malachite	Hydrous copper carbonate	Do.
Manganite	Manganese oxide	Force Crag mine
Magnetite	Magnetic pyrites	Igneous rocks
Marcasite	White pyrites	Garrigill mines
Melaconite	Black oxide of copper	Roughtengill
Mimetisite	Arseniate of lead	Do.
Minium	Native red lead	Alston
Mispickel	Arsenical iron	Brandy Gill
Molybdenite	Sulphide of molybdena	Do.
Molybdine	Molybdic ochre	Caldbeck Fells
Nickeline	Nickel arsenide	Vein in High Snab Bank, Newlands
Olivenite	Hydrous copper arseniate	Goldscope
Pharmacosiderite	Hydrous iron arseniate	Caldbeck Fells
Pitchy copper	Silicate of copper and ferric hydrate	Dalehead mine, &c.
Psilomelane	Peroxide of manganese	Force Crag mine
Pyrolusite	Manganese bin-oxide	Caldbeck Fells
Pyromorphite	Phosphate of lead	Roughtengill
Scheelite	Tungstate of lime	Brandy Gill
Siderite	Carbonate of iron	Do.
Silver	Silver	In lead and copper ores
Smaltine	Cobalt diarsenide	Cobalt mine,near Scar Crag
Smithsonite	Hydrous zinc monosilicate	Roughtengill
Stolzite	Tungstate of lead	Force Crag mine
Tetradymite	Telluric bismuth	Brandy Gill
Turgite	Hydrated iron oxide	Iron mines, Harcla
Wad	Earthy manganese	Millbeck Gill
Wolfram	Manganese and iron tungstate	Brandy Gill
Wolframine	Oxide of tungsten	Carrock
Wulfenite	Variety of molybdena	Do.

In the compilation of the foregoing list I have been largely indebted to the valuable series of Papers entitled "Contributions towards a List of the Minerals occurring in Cumberland and Westmorland," by J. G. Goodchild, F.G.S., which appeared in the *Transactions of the Cumberland and Westmorland Association*; and also to the List of Minerals in *Jenkinson's Practical Guide to the English Lakes*, by Mr. Bryce Wright.

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